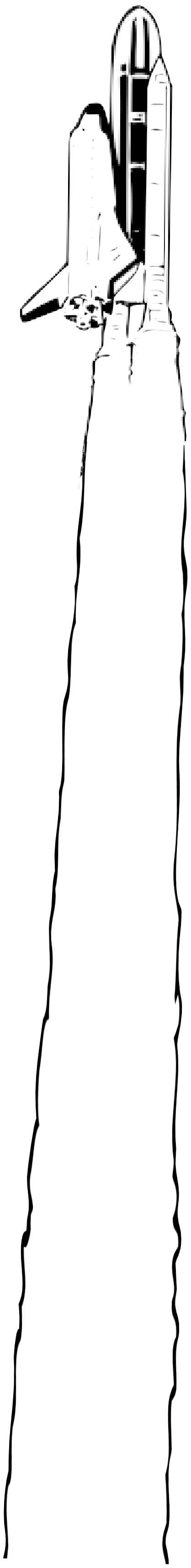
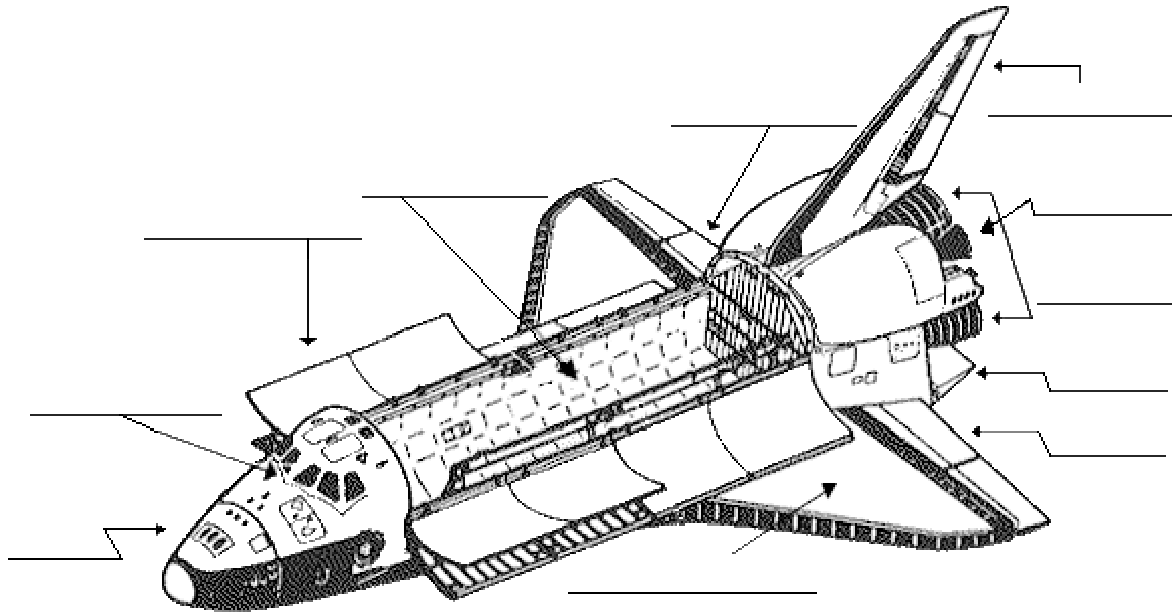
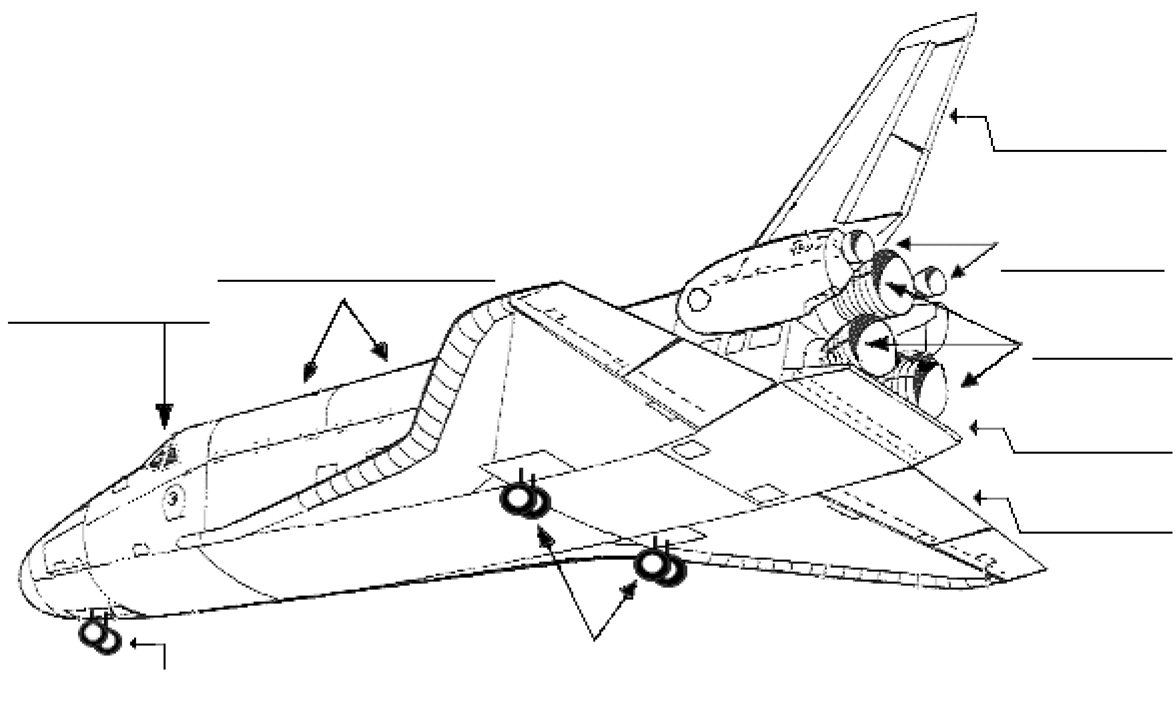
Space Shuttle Aeronautics

Section Contents

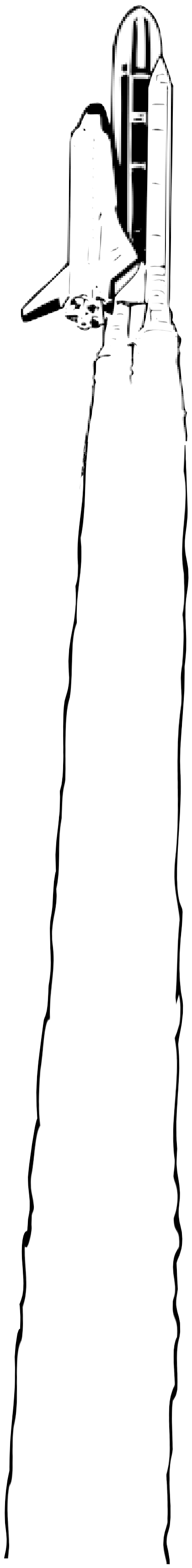
Label the Parts of the Space Shuttle

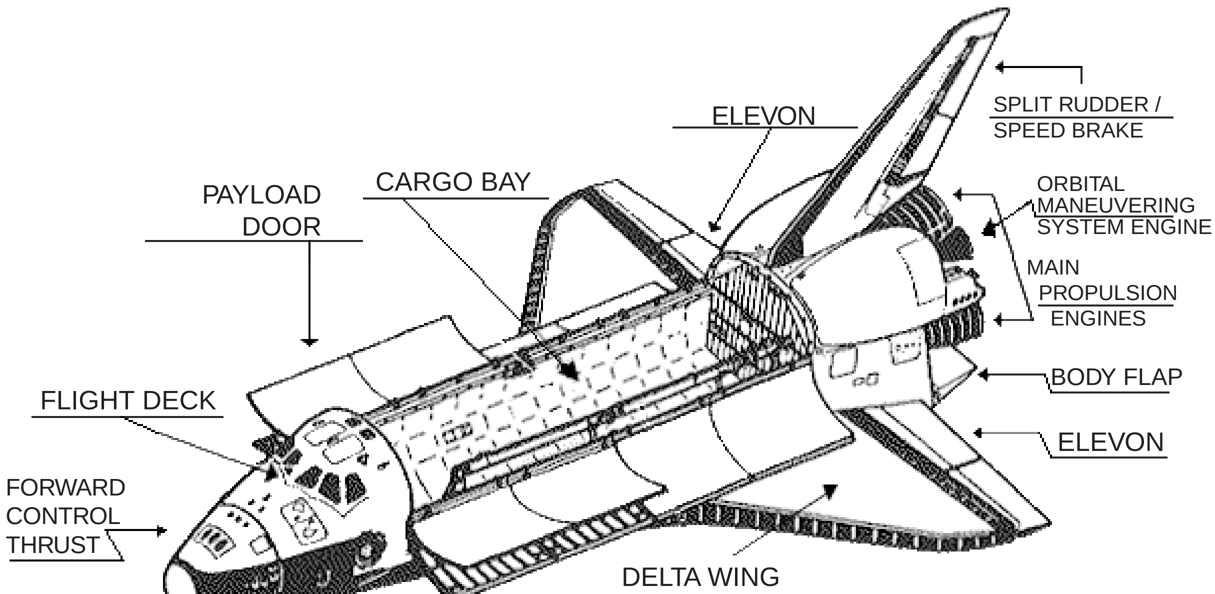


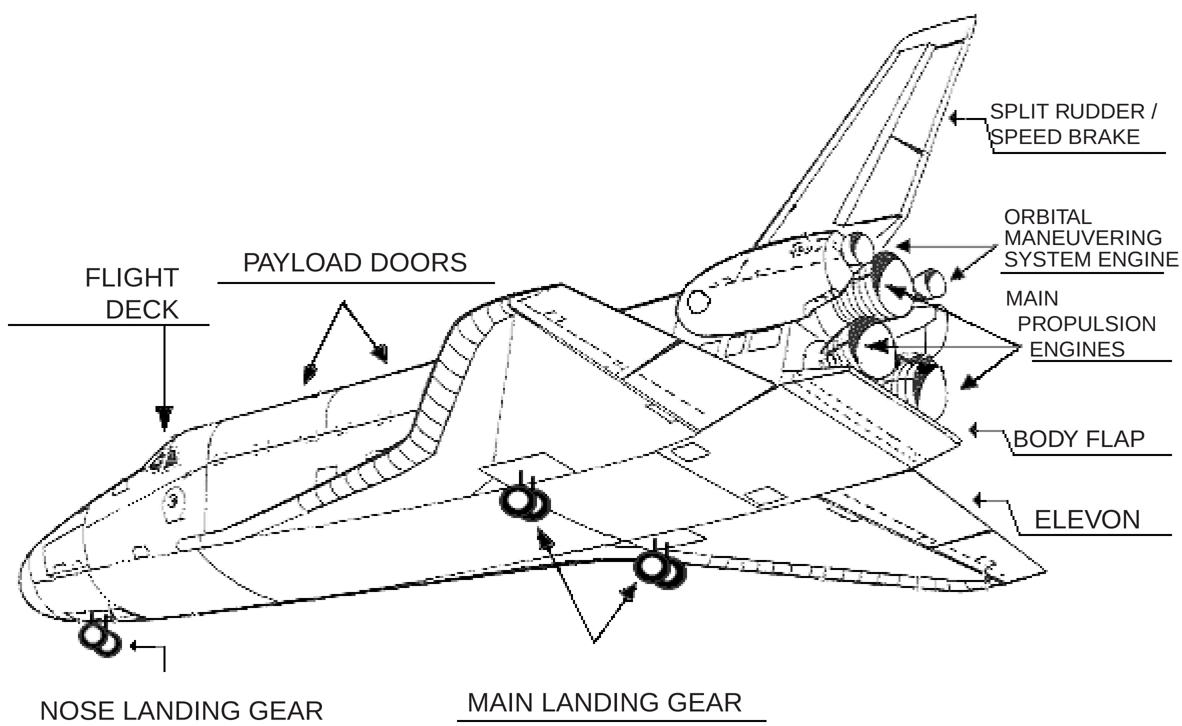




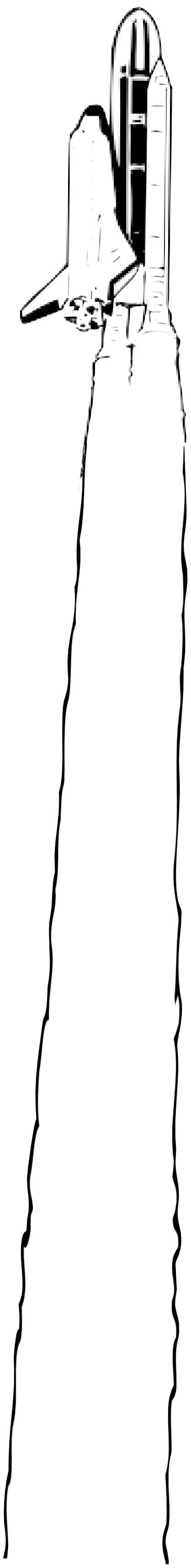
Label the Parts of the Space Shuttle - Key







Space Shuttle Vocabulary



Body Flap
A control surface hinged to the lower section of the aft fuselage. It is used during descent to control the motion of pitch.

Cargo Bay
The center of the orbiter's fuselage also called the payload bay.

Delta Wings
A sweepback wing design that looks like a triangle from above.

Elevon
A control surface used once the returning shuttle has entered the atmosphere; it acts like a combination of an aircraft elevator and aileron, controlling pitch and roll.

Flight Deck
Part of the crew compartment; the commander, pilot, missions specialist, and one payload specialist sit here during launch and landing.

Forward Control Thrusters
Small rocket engines that maneuver the orbiter in space. These are located around the orbiter's nose.

Main Landing Gear
There are two main landing gears located under the orbiter's belly, each with two tires.

Main Propulsion Engine
The three SSMEs (Space Shuttle Main Engines) located on the orbiter's aft end. The SSME is one of the most advanced rocket engines ever built.

Nose Landing Gear
Landing gear assembly located under the orbiter's nose with two tires.

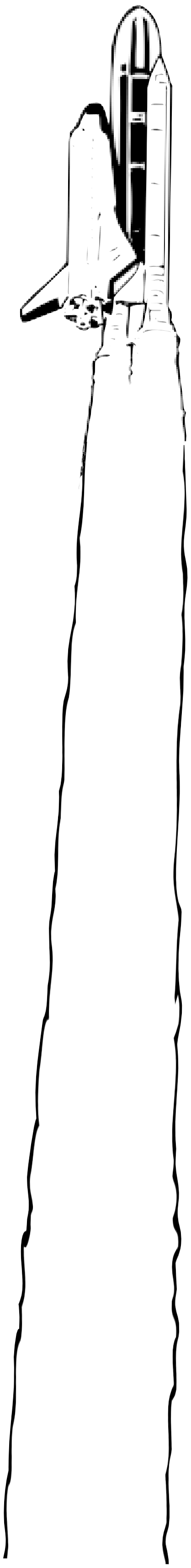
Orbital Maneuvering System (OMS)
Two OMS engines are mounted in external pods on each side of the aft fuselage. These power the orbiter during orbital insertion and de-orbit.

Payload Doors
Two curved cargo-bay doors located on the top part of the fuselage and opened soon after reaching orbit.

Reaction Control System (RCS)
A set of engines located on each side of the aft fuselage that are used to control the motions of roll, pitch and yaw when the orbiter is maneuvering out of orbit and into re-entry of the atmosphere.

Split Rudder / Speed Brake
A control surface located on the vertical stabilizer (tail section) that splits apart vertically to increase drag and slow the aircraft during descent and landing. When both sections are moved together, it acts as a rudder and controls the motion of yaw.

Space Shuttle Word Search



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Astronauts
Crew Compartment
Deorbit
External Tank
Landing
Launch
Lift-Off
Main Gear
Maintenance
Missions
NASA
Nose Gear
Operations
Orbiter
Orbiter Insertion
Payload Bay
Solid Rocket Boosters
Space Shuttle
Splashdown
Tank Separations
Thrust
Touchdown
Wings

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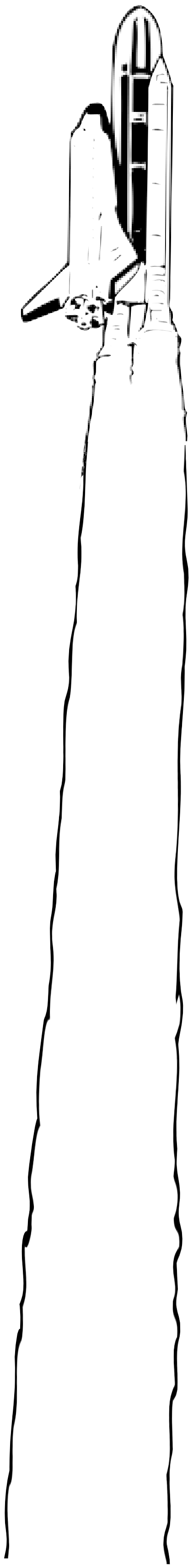
Space Shuttle Word Search - Key



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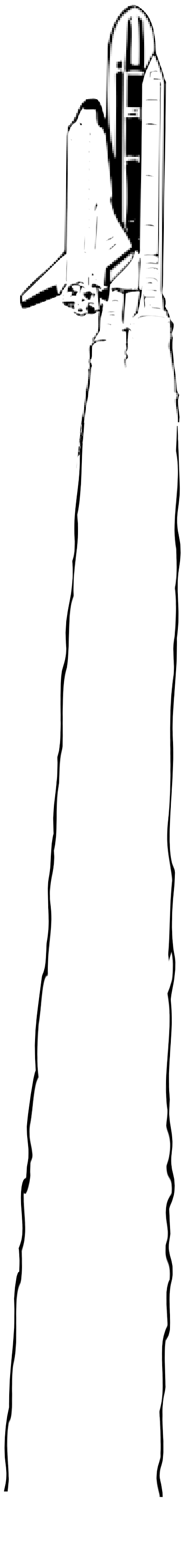
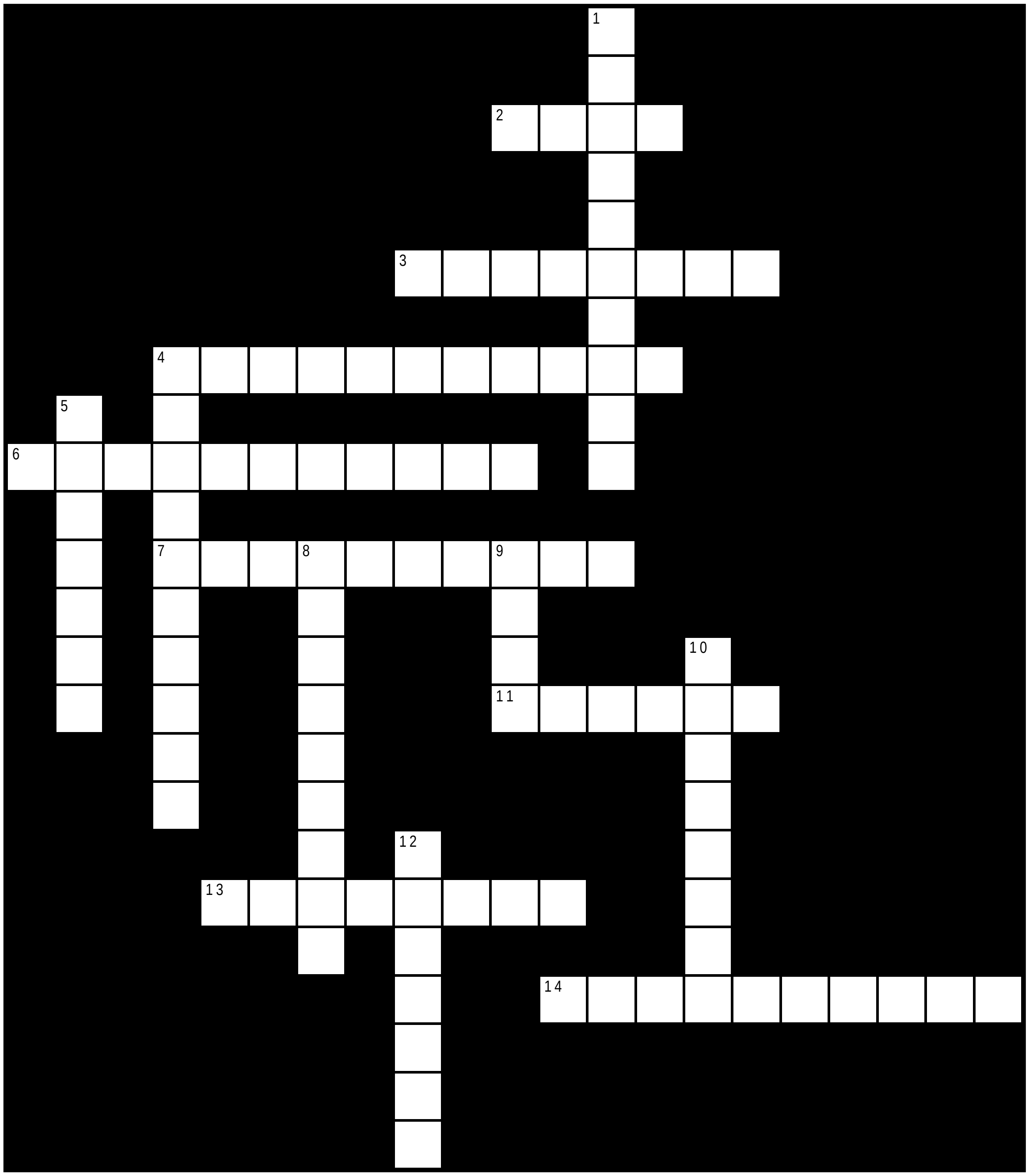
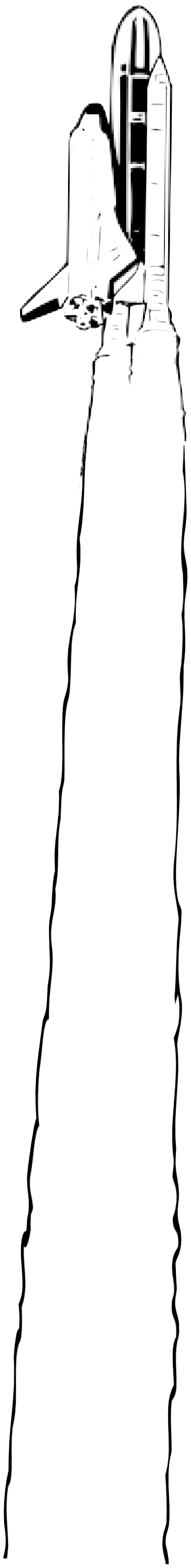
Space Shuttle Vocabulary Crossword Puzzle





Space Shuttle Vocabulary Crossword Puzzle



ACROSS

2 Landing gear located under the orbiter's belly.

3 A control system using a set of engines located on each side of the aft fuselage during re-entry. First word only.

4 A control surface located on the vertical stabilizer controlling yaw.

6 This engine system is used to move the orbiter into orbit and out of orbit. Middle word used.

7 Triangular shaped wings.

11 A control surface that combines the work of an aileron and an elevator.

13 The center of the orbiter's fuselage that holds the payload.

14 The 3 Space Shuttle Main Engines (SSME) give this.

DOWN

1 Part of the crew compartment.

4 Located on the tail section it slows the orbiter's speed.

5 These doors open the cargo bay.

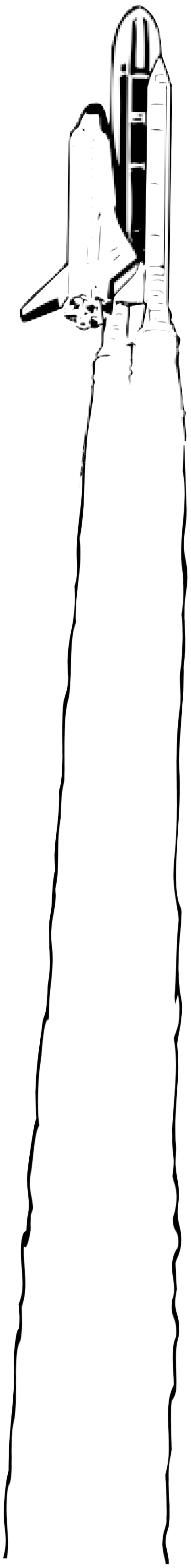
8 These small rocket engines located around the orbiter's nose are the forward control ---------.

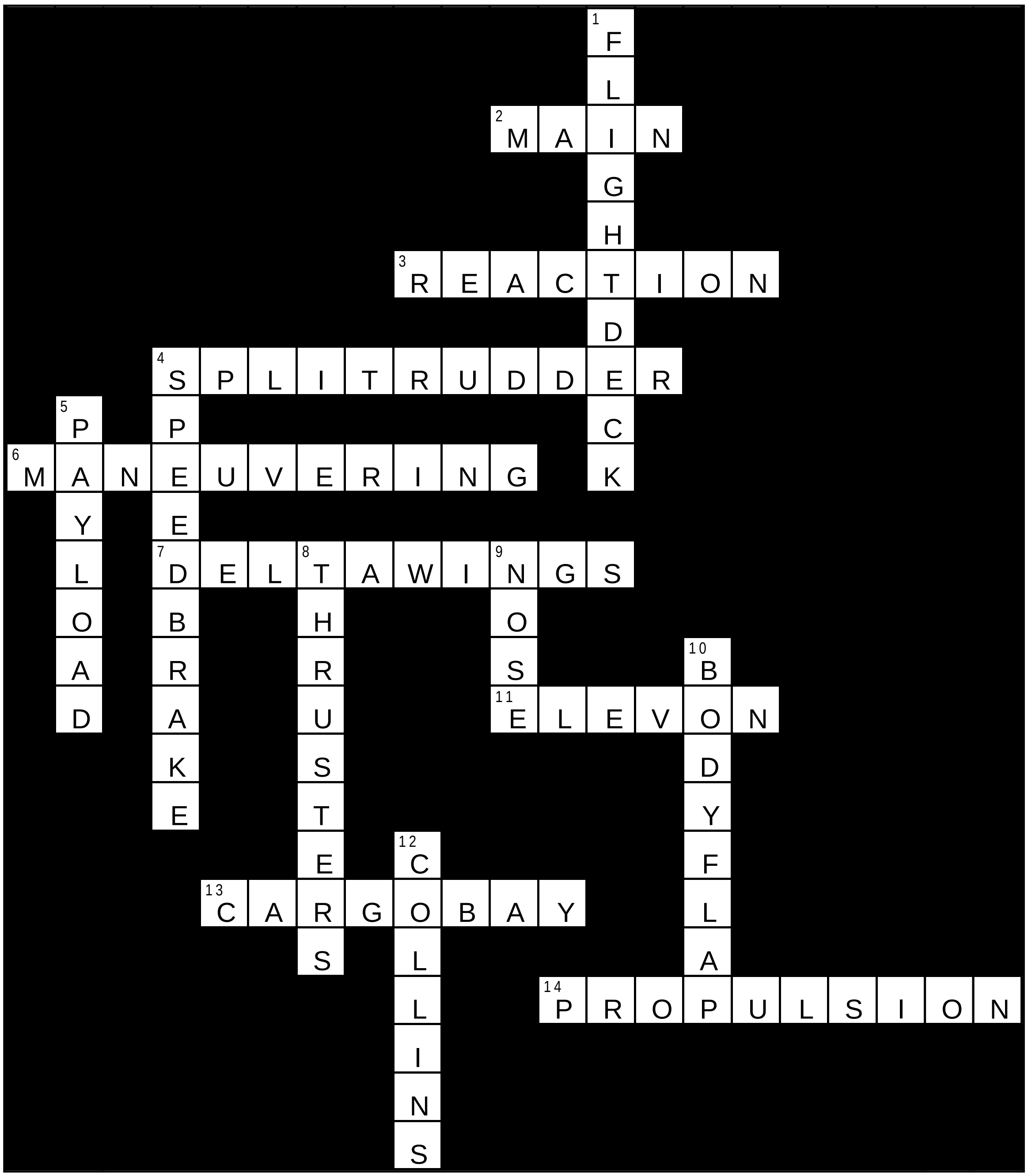
9 Landing gear located under this front end of the orbiter.

10 A hinged control surface connected to the aft fuselage.

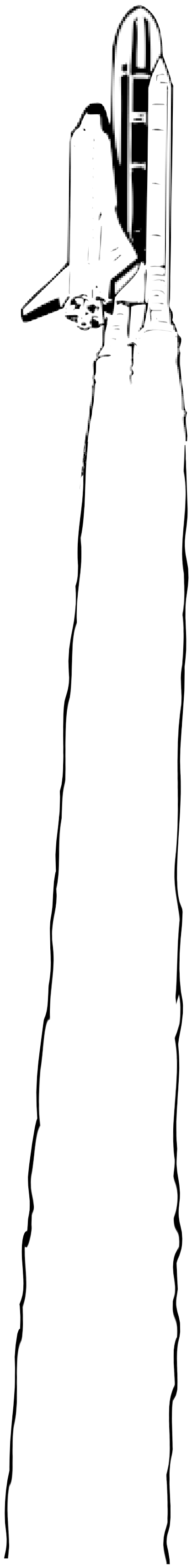
12 Commander of STS-93

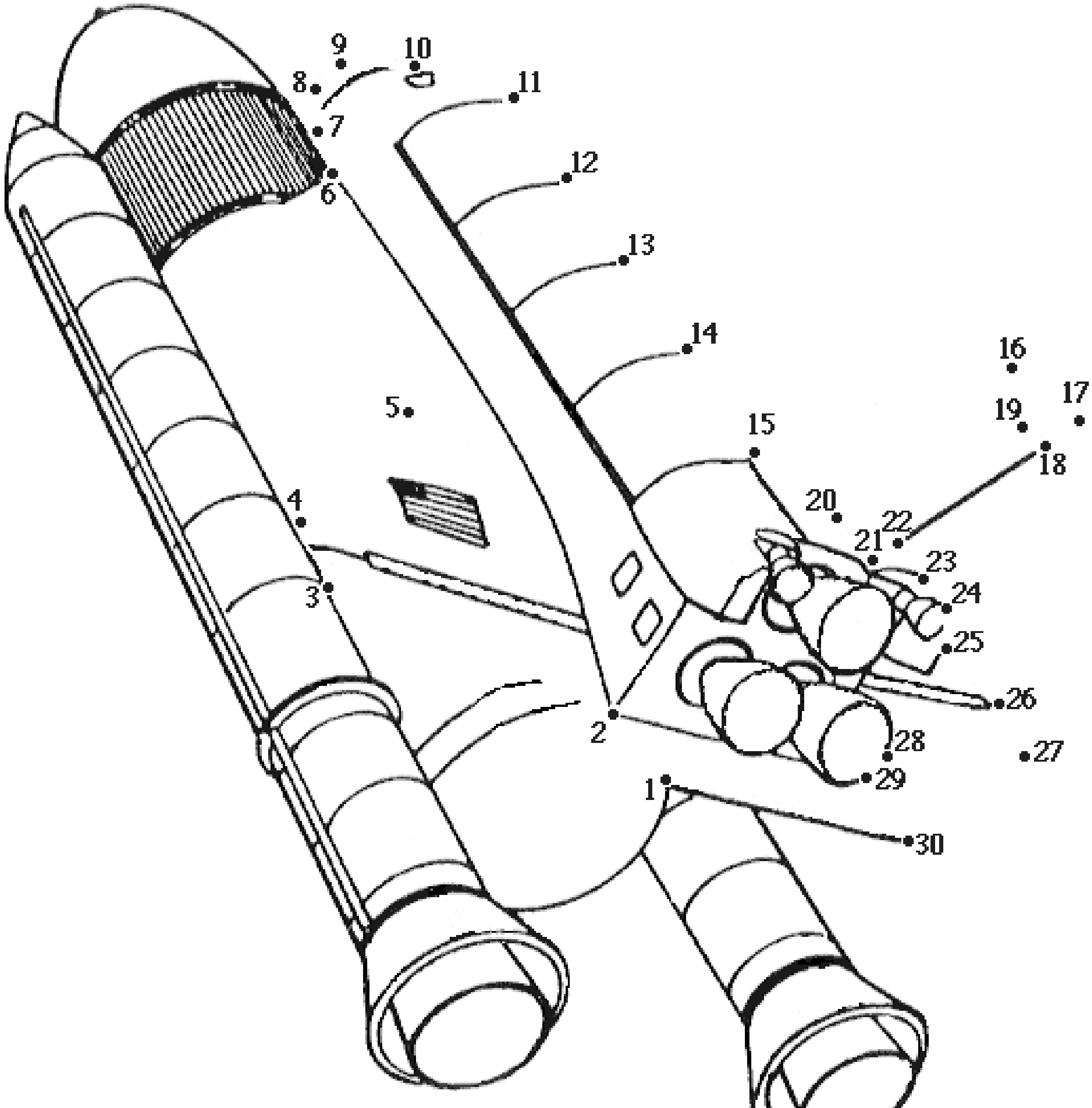
Space Shuttle Vocabulary Crossword Puzzle - Key



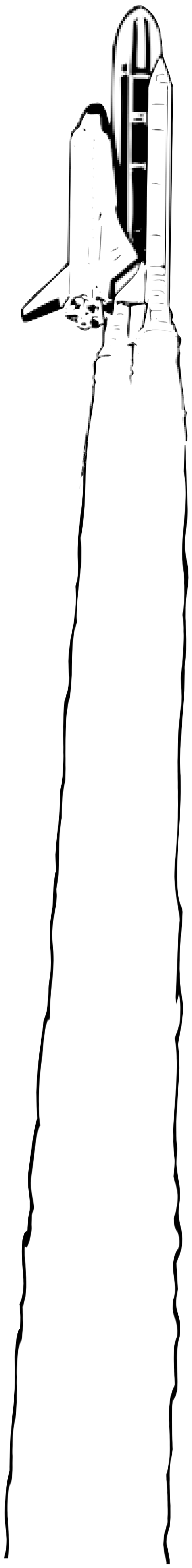


Space Shuttle Dot-to-Dot

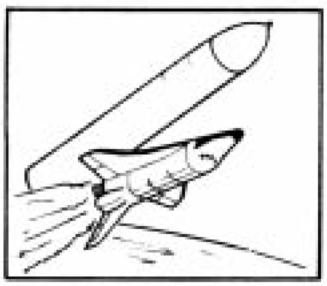


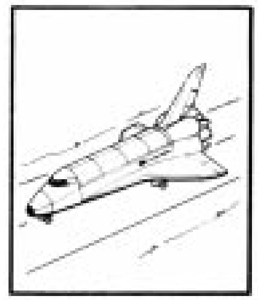


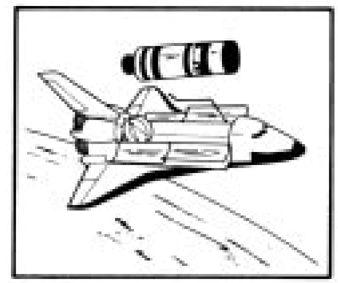
Phases of a Space Shuttle Mission

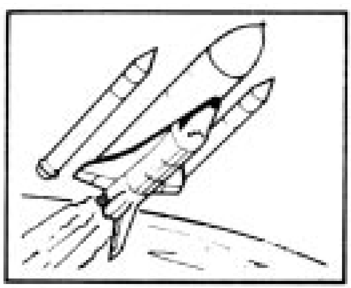


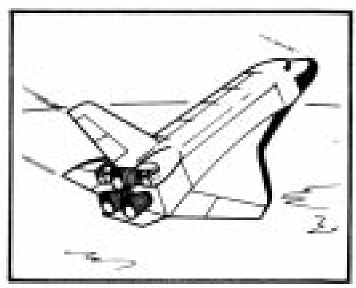
Directions: Cut out each picture below and place them in their proper order in the boxes on the next page. Underneath each box, label that phase of the space shuttle mission. Use the list at the bottom of this page to help you.

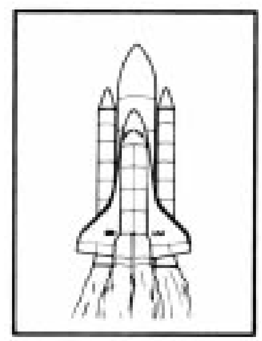










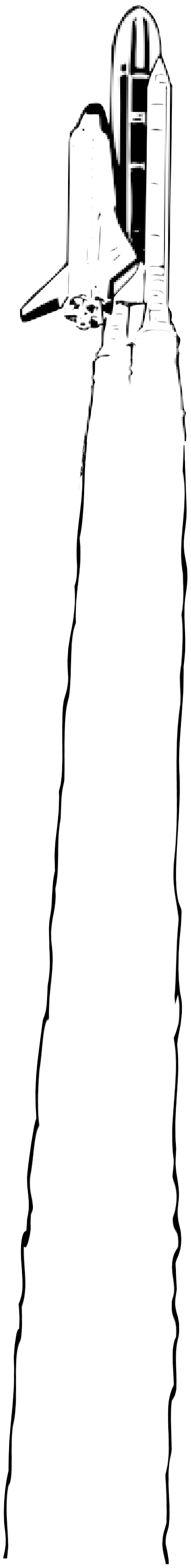


<u>Labels for each phase in a space shuttle mission</u>

Re-entry **Booster Separation** **Orbit Operations**

Launch **Landing** **External Tank Separation**

Phases of a Space Shuttle Mission



Directions: After you cut out the pictures from the first page, glue or tape them in their proper order in the boxes below. Underneath each box, label that phase of the space shuttle mission. Use the list at the bottom of the first page to help you.

1. ______________________

4. ______________________

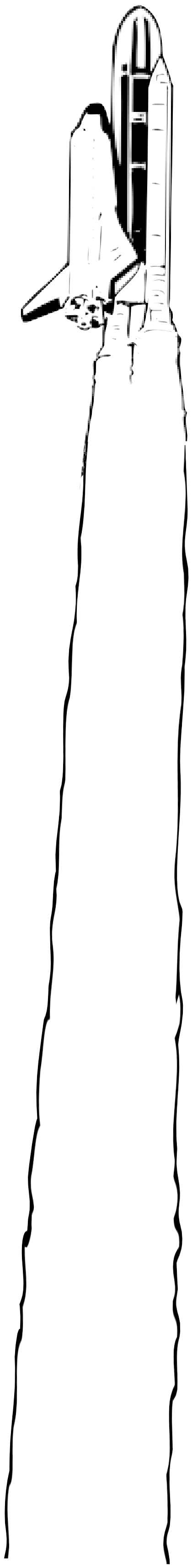
2. ______________________

5. ______________________

3. ______________________

6. ______________________

Phases of a Space Shuttle Mission - Key



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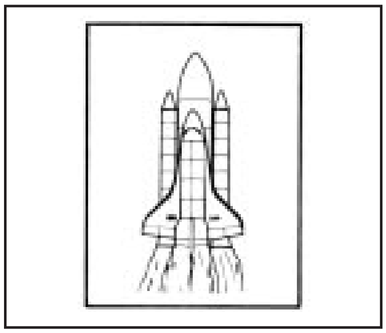
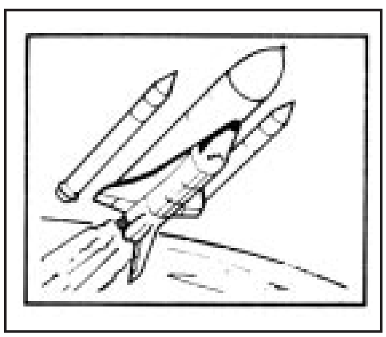
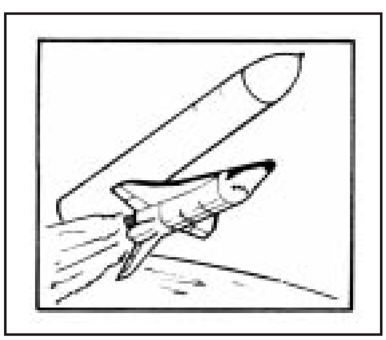


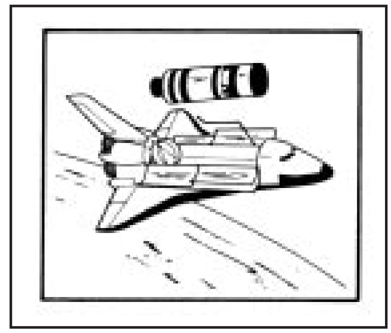
1. Launch



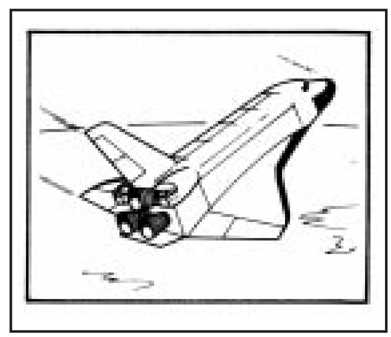
2. Booster Separation



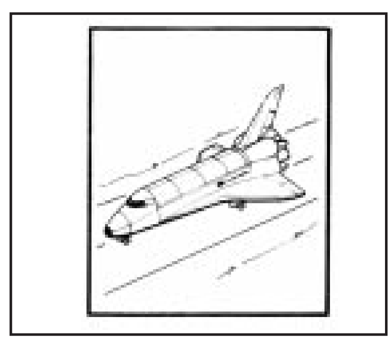
3. External Tank Separation



4. Orbit Operations

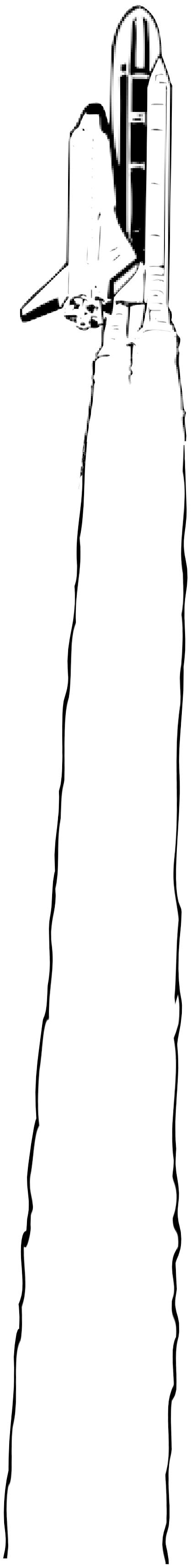


5. Re-entry



6. Landing

Student Reading: Aeronautics of the Space Shuttle



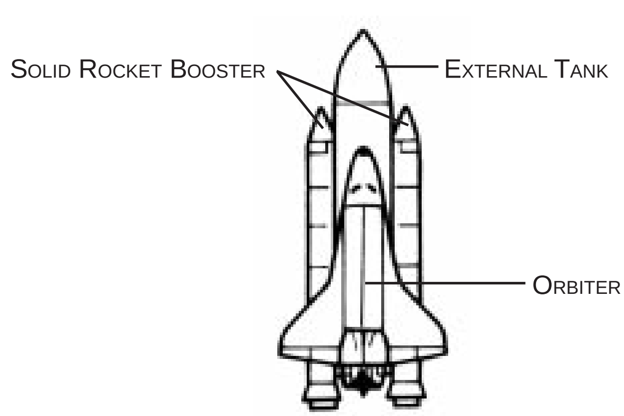
The Space Shuttle is a Lifting Body

On August 12, 1977 a specially modified Boeing 747 jetliner was giving another aircraft a piggyback ride. Approximately 24,000 feet above the Mojave Desert a high-tech glider was released from its flying perch. It glided effortlessly without engine power to a smooth landing on the desert floor. A new era in space transportation had begun.

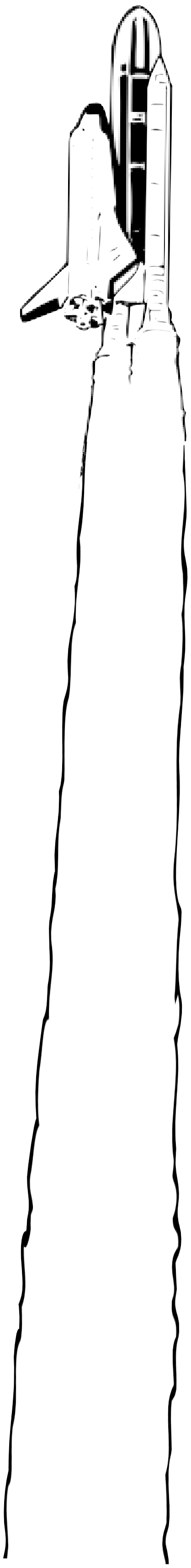
That high-tech glider was the space shuttle. The space shuttle is designed to simply ferry or “shuttle” people, satellites and other cargo between earth and space. It is a reusable spacecraft unlike any other that had come before it. It is a more efficient and economical vehicle as compared to its predecessors: capsules and rockets. The space shuttle, with a shape like a bulky glider, is actually a lifting body. A lifting body is a specially constructed spacecraft that cannot launch under its own power, but needs additional rocket engines for thrust. The space shuttle is a unique lifting body in that it is a high-tech glider.

Basic Structure

The space shuttle is made up of four parts: an orbiter (the shuttle itself), two solid rocket boosters (both reusable) and one external fuel tank (which is not reusable). This space craft is launched in an upright position attached to the 2 solid rocket boosters and the external fuel tank. At launch, the orbiter’s 3 main engines are fired (fueled by the external fuel tank) as well as the solid rocket boosters. Together they provide the shuttle with the millions of pounds of thrust to overcome the earth’s gravitational pull.

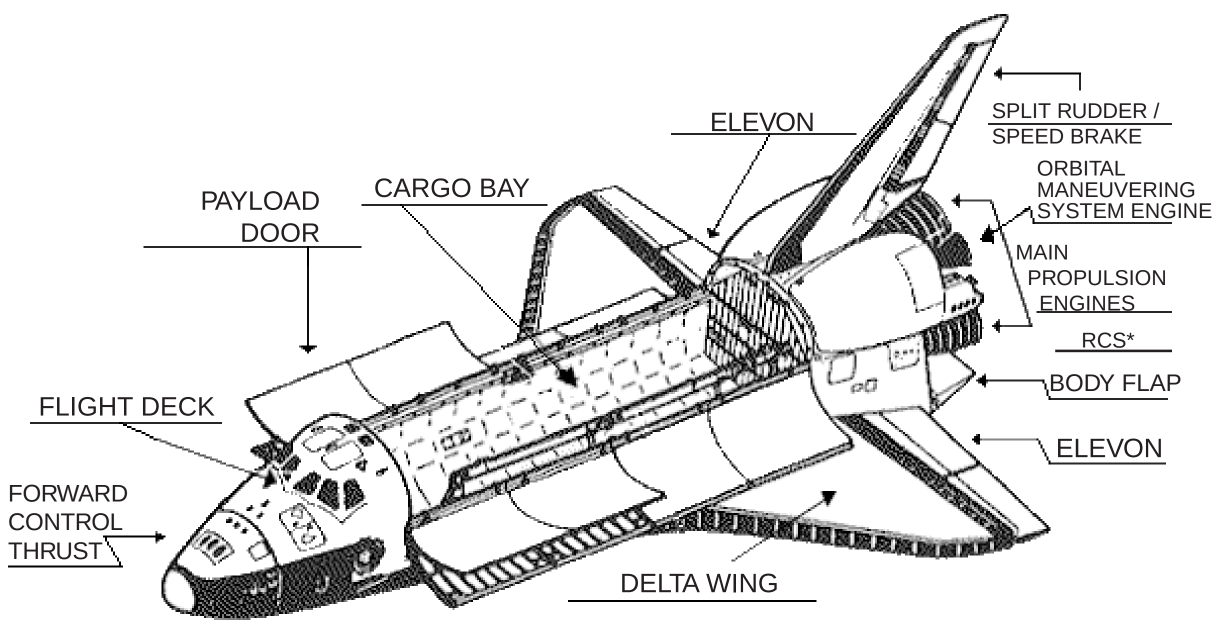


Aeronautics of the Space Shuttle (continued)



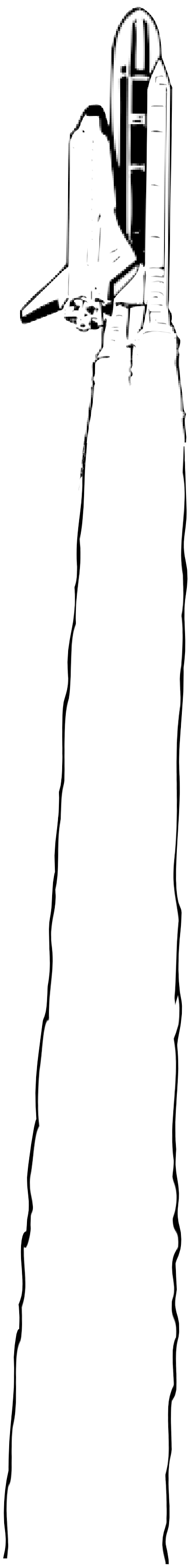
The Orbiter as a High-Tech Glider

The orbiter is shaped much like an airplane. It has many of the same parts as an airplane except for its engine configurations. The orbiter has wings that create lift. It uses a double-delta wing configuration to achieve the most efficient flight during hypersonic speed as well as providing a good lift-to-drag ratio during landing. For control, each wing has an "elevon". An elevon is a combination of an elevator and an aileron. On an airplane, the elevator controls the motion of pitch (nose up, nose down). On most airplanes, the elevator is located on the horizontal stabilizer as part of the tail section. The ailerons are found on most airplanes at the trailing edge of each wing. Ailerons control an airplane's roll motion. Because of the orbiter's delta wing configuration, the elevators and ailerons are combined as elevons and placed at the trailing edge of each wing. The orbiter's vertical stabilizer (fin) has the rudder which controls its yaw (nose left, nose right). The split-rudder on the orbiter works as a rudder and also as a speed brake (found on most airplanes as a spoiler located on the wing). It does this by splitting in half vertically and opening like a book. This deflects the airflow, increases drag and decreases the orbiter's speed as it rolls along the runway upon landing.



* RCS = Reaction Control System

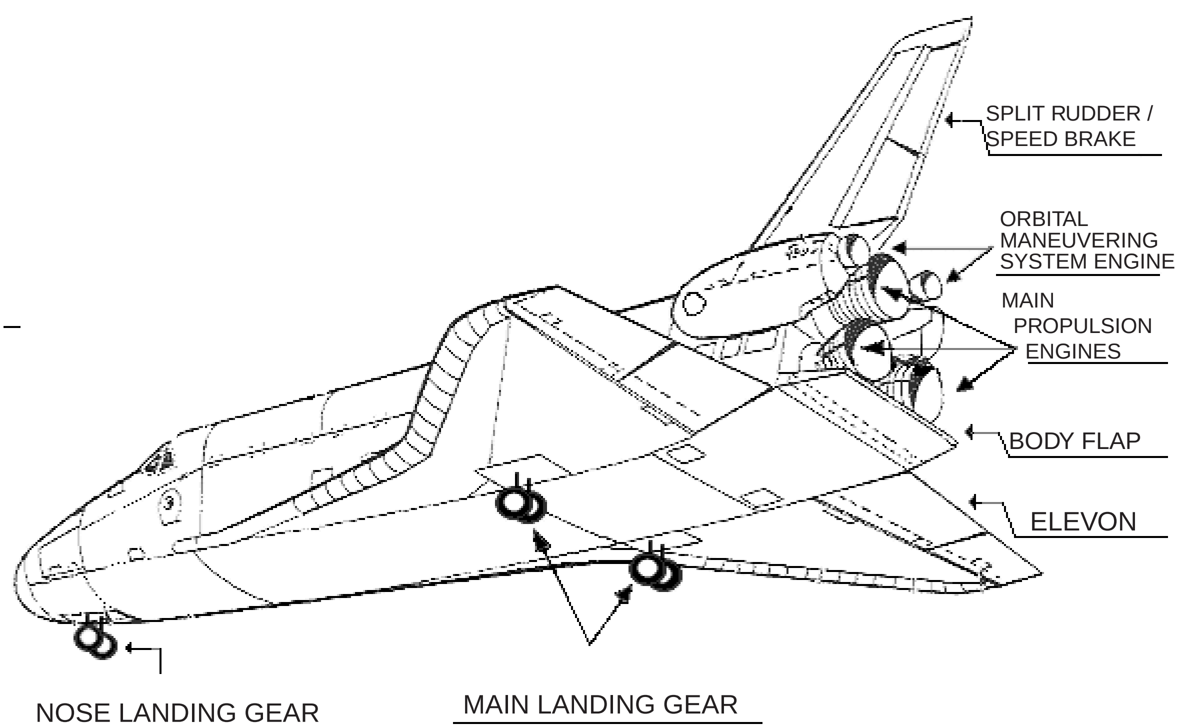
Aeronautics of the Space Shuttle (continued)



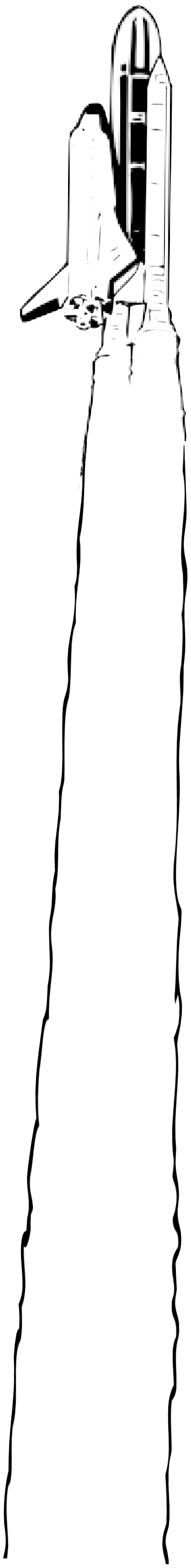
The airplane-like control surfaces on the orbiter are useless in the vacuum of space. However, once the orbiter re-enters the earth's atmosphere, these control surfaces interact with the air molecules and their airflow to control the orbiter's flight path.

The engines are the major difference between this high-tech glider and airplanes. The orbiter has the OMS (orbital maneuvering system) engines as well as the RCS (reaction control system) engines. The shuttle maneuvers into orbit using its orbital maneuvering system (OMS). The OMS has 2 rocket engines located on the outside of the orbiter, one on each side of the rear fuselage. These rockets give the orbiter the thrust it needs to get into orbit, change its orbit, and to rendezvous with a space station or another space vehicle. The OMS is also used to exit orbit for re-entry into the earth's atmosphere.

The second set of small engines is the reaction control system (RCS) engines. The RCS engines allow the commander to perform the motions of roll, pitch and yaw while the orbiter is moving out of orbit and into re-entry of the earth's atmosphere. The RCS engines are also used while the orbiter is maneuvering in the upper atmosphere.



Aeronautics of the Space Shuttle (continued)



Re-entry and Landing

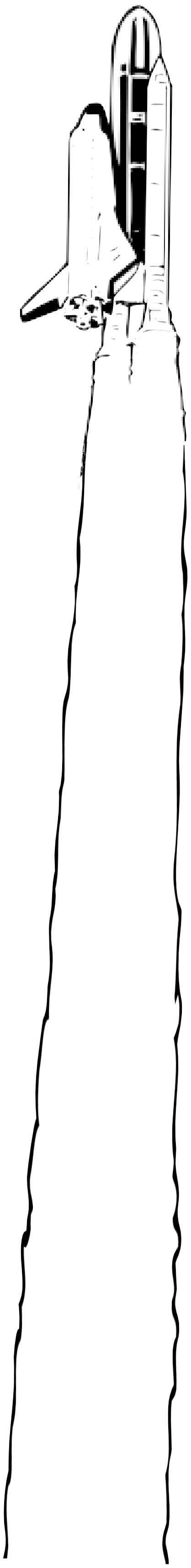
The commander begins the de-orbit burn by firing the orbiter's engines to slow its speed and take it out of orbit. Using the RCS engines, the orbiter is turned around so that it is moving backwards at a slower speed. To maneuver the orbiter while it is in this position, the commander uses the RCS engines to control roll, pitch and yaw motions. The OMS engines (space engines) are then fired, taking the orbiter out of orbit and thrusting it into the earth's upper atmosphere. The RCS engines are used one last time to turn the orbiter around so that it is moving nose forward and pitched up slightly. In the upper reaches of the atmosphere the vehicle's motions of yaw, pitch and roll are controlled by the RCS engines. As the atmosphere thickens, the airplane control surfaces become usable. The orbiter re-enters the atmosphere at a high angle of attack (about 30 degrees). This high angle of attack is used to direct most of the aerodynamic heating to the underside of the vehicle where the heat resistant tiles give the greatest amount of protection.

At an altitude of approximately 30 miles, the orbiter makes a series of maneuvers and S-turns to slow its speed. At 9.5 miles in altitude and at a speed of Mach 1, the orbiter can be steered using its rudder. The on-board computers fly the orbiter until it goes subsonic (slower than the speed of sound: Mach 1). This happens about 4 minutes before landing. At this time the commander takes manual control of the orbiter and flies a wide arc approach. At 7.5 miles from the runway, the orbiter is flying about 424 miles per hour at an altitude of 13,365 feet. About 2 miles from the runway, the orbiter is flying at nearly 360 miles per hour on a glide slope of 22 degrees.

Once lined up with the runway on approach, the orbiter continues its steep glide slope of 18 - 20 degrees. The commander levels the descent angle at a final glide slope of 1.5 degrees by performing a "flare maneuver". The nose of the orbiter increases its pitch (noses up) which slows its speed. The orbiter touches down at a speed of about 215 miles per hour. It is slowed and eventually brought to a stop by the speed brake, wheel brakes and a drag chute.

It is this unique aerospace vehicle, a lifting body, that launches like a rocket, orbits like a spacecraft and lands like a glider that continues to link earth and space.

Student Worksheet: Aeronautics of the Space Shuttle



Directions: After reading "Aeronautics of the Space Shuttle", answer each question below by circling the letter of the correct answer.

1. Name the vehicle that is an example of a lifting body.

   A. a Boeing 747
   B. a glider
   C. the orbiter

2. The orbiter uses what type of wing?

   A. delta wing
   B. sweepback wing
   C. straight wing

3. Which part of the space shuttle is NOT reusable?

   A. orbiter
   B. external fuel tank
   C. solid rocket booster

4. Name the "space engines" used by the orbiter to enter, exit and change orbit.

   A. solid rocket booster
   B. orbital maneuvering system
   C. reaction control system

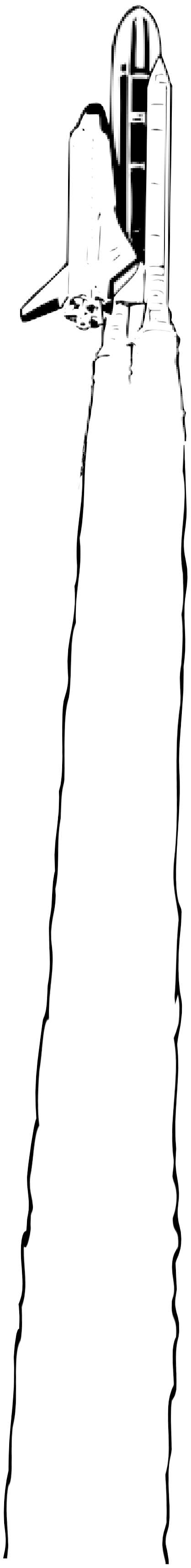
5. Name the airplane control surface that is on the trailing edge of the orbiter's wings.

   A. aileron
   B. rudder
   C. elevon

6. Name the engine system that is used to control the orbiter's motions of roll, pitch and yaw while it is in the upper atmosphere.

   A. reaction control system (RCS)
   B. orbital maneuvering system (OMS)
   C. orbiter reaction system (ORS)

Student Worksheet: Aeronautics of the Space Shuttle (continued)



7. What is the purpose of the S-turns during landing?

   A. to reduce heat
   B. to slow the orbiter's speed
   C. to burn extra fuel

8. The orbiter's split-rudder is used to do what?

   A. control yaw
   B. slow the orbiter
   C. both of the above

9. The orbiter lands on the runway moving at about what speed?

   A. 424 mph
   B. 215 mph
   C. Mach 1

10. The major difference between the orbiter and an airplane is found with what part?

    A. elevons
    B. wings
    C. engines

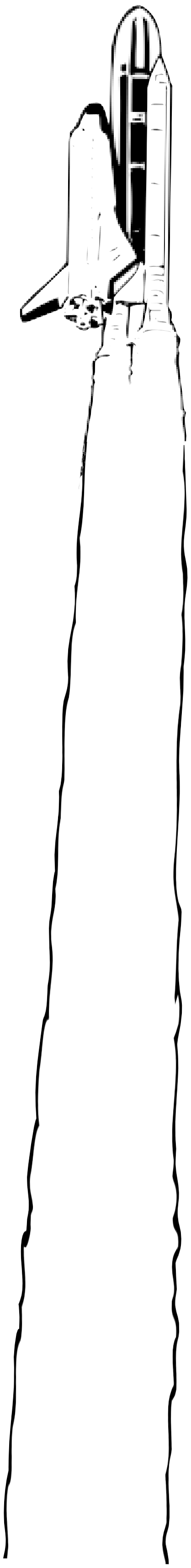
11. An elevon is a control surface that combines which two control surfaces?

    A. aileron and elevator
    B. elevator and rudder
    C. wing and aileron

12. At what speeds does the orbiter fly?

    A. hypersonic
    B. supersonic and subsonic
    C. all of the above

Student Worksheet: Aeronautics of the Space Shuttle - KEY



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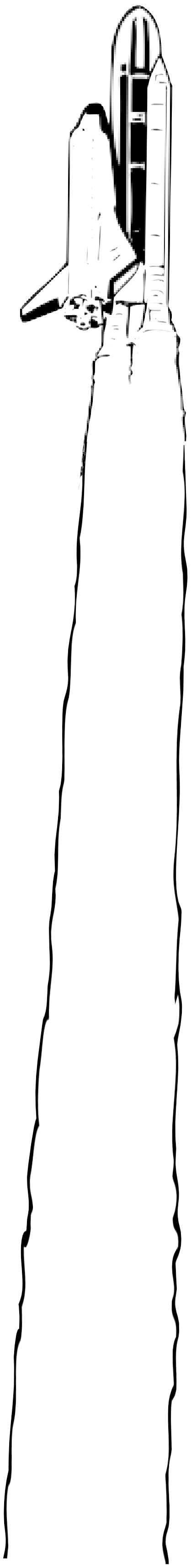
Student Worksheet: Aeronautics of the Space Shuttle (continued) - KEY



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   A. 424 mph
   B. 215 mph
   C. Mach 1

10. One major difference between the orbiter and an airplane is found with what part?

    A. elevons
    B. wings
    C. engines

11. An elevon is a control surface that combines which two control surfaces?

    A. aileron and elevator
    B. elevator and rudder
    C. wing and aileron

12. At what speeds does the orbiter fly?

    A. hypersonic
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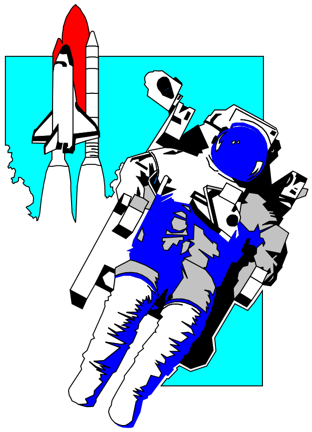
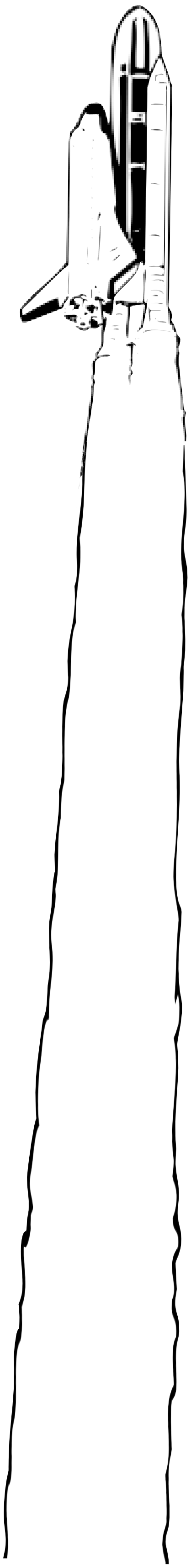


Student Mathematics Activity: Glide Slope

Student Mathematics Activity: Glide Slope



Grade Levels: 4 - 8

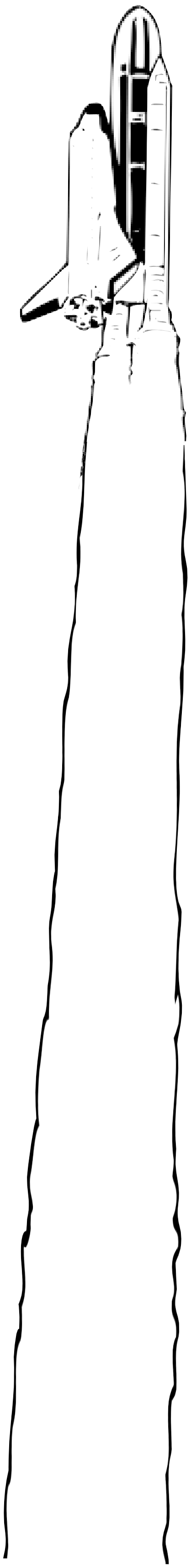
Teacher Overview Outline

I. Introduction (pages 23 - 37)
- Space Shuttle Glider Activity-Teacher Information
- Key Questions
- Time Frame
- Getting Ready
- Prerequisite Knowledge for Students
- Materials
  - For each student
  - For each team
  - For the class
- Teacher's Answer Key

II. Classroom Activity (pages 38 - 39)
- Session 1
- Session 2
- Session 3
- Session 4
- Session 5
- Session 6
- Session 7

III. Student Handouts (pages 40 - 72)
- Student Reading
  - Landing the Orbiter
  - Angle of Attack
  - Glide Slope
- Vocabulary List
- Space Shuttle Glider Activity - Student Information
- Instructions for Building the Space Shuttle Glider
- Team Members and their Roles
- Instructions for Landing Procedures
- Landing Data Collection Sheet
- Math Worksheet of Prerequisite Knowledge - practice exercises
- How to Compute Glide Slope - practice exercises
- How to Compute Flight Time
- How to Compute Average Speed - practice exercises
- Table for Determining Glide Slope
- Purpose of a Scatter Plot
- How to Create a Scatter Plot - practice exercises

Student Mathematics Activity: Glide Slope

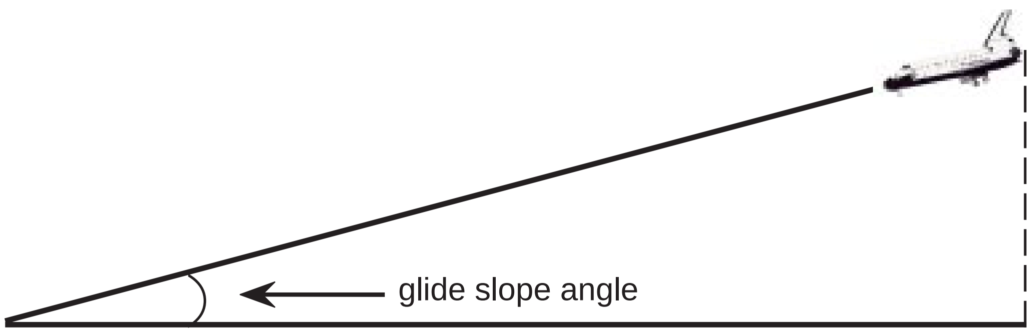


Introduction

This activity is designed to introduce students to the concept of glide slope, which is the angle that the U.S. Space Shuttle orbiter approaches for landing upon return from space orbit. This five to seven session activity is appropriate for students in grades 4-8. The lesson consists of a hands-on math activity with worksheets and photos depicting the experiment process.

Example #1

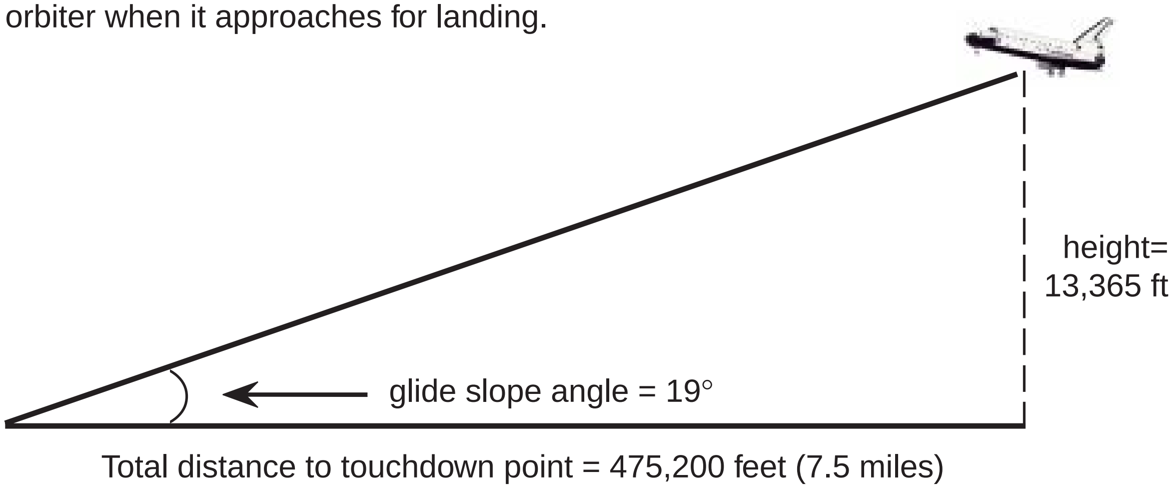
Glide slope angle can be determined when the orbiter's nose is pointing down.

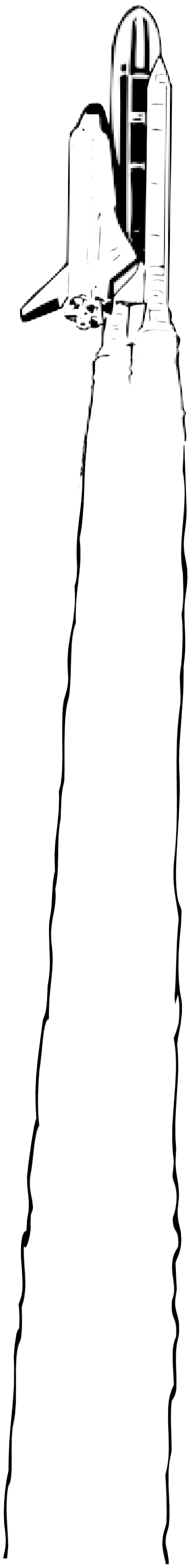


Example #2

Here is an example of the glide slope angle when the orbiter's nose is pointing up.

The measurements shown are possible dimensions for the U.S. Space Shuttle orbiter when it approaches for landing.

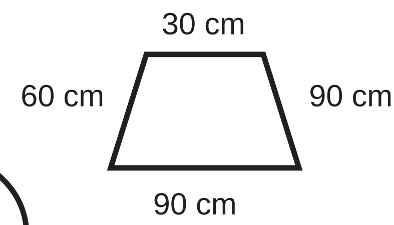




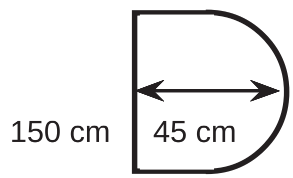
Space Shuttle Glider Activity - Teacher Information

In this activity the students will achieve a greater understanding of glide slope by manipulating the measurements that affect the landing of the shuttle orbiter. The students will construct a space shuttle glider (that you can download from the Web) which is a 1cm:300cm scale of the actual U.S. Space Shuttle orbiter. Teachers: You may want to draw the actual size of the cockpit window or the tip of the nose to give the students an idea of the actual size of the orbiter.

The cockpit window on the side of the orbiter would have the following actual size measurements:



The nose of the orbiter would have the following actual size measurements:

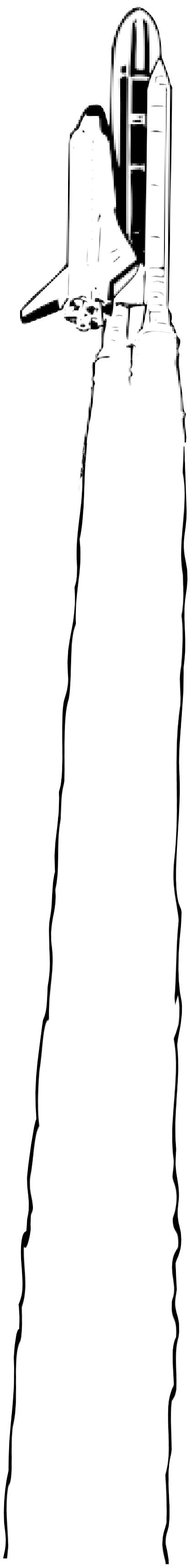


Then, they will have the opportunity to reenact the landing procedure by controlling glide slope, and piloting the glider in for a smooth landing. They will record their results to further explore the meaning of glide slope, flight time and distance, and compare their data to the glide slope, flight time and distance of NASA's space shuttle orbiter landings (see table below).

Landing Data Collection Sheet: Space Shuttle

Team	Height of orbiter from ground parallel to **y-axis** (inches) 160,380 (13,365 feet)
Pilot	Total distance to touchdown point along **x-axis** (inches) 475,200 (7.5 miles) (measure distance on the ground)
Copilot	Slope = $\frac{\textbf{y-axis}}{\textbf{x-axis}} = \frac{160{,}380}{475{,}200}$ (fraction) 0.3375 (decimal equivalent)
Mission Control Center	Glide Slope (use table) 19 degrees
Mission Specialsit	Flight Time (in seconds) 120 seconds
	Average Speed: Total Distance / Flight Time (in inches / second) 3960 (225 mph)

This entire activity is done in conjunction with other activities under Space Shuttle Aeronautics found on NASA Quest's Female Frontiers Web Site at:
http://www.quest.arc.nasa.gov/space/frontiers



Key Questions

- Why does the orbiter reenter the atmosphere at such a high velocity?
- Why is it necessary for the orbiter to reenter the atmosphere at such a steep angle of attack?
- What strategies does the orbiter take to slow down before landing?
- Does glide slope affect the speed of the glider?

Time Frame

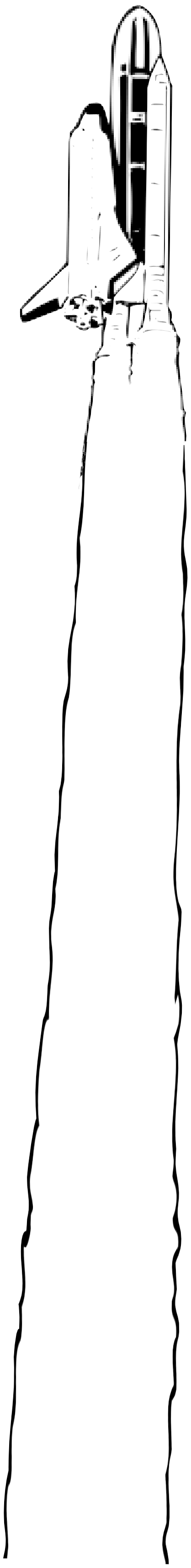
Five to Seven class sessions of 45 to 60 minutes each.

Getting Ready

1. Run all multiple copies of each student handout.
2. Read through the lesson plan.
3. Review Math Worksheets and other math concepts needed for this activity.
4. Assemble a glider for yourself.
5. Decide where the landings will take place.
6. Prepare the area for glider landings.
7. Try a few practice runs yourself on each landing site.
8. Place students into groups of 3-4 for each landing site.
9. Be sure each group has the necessary materials: gliders, pencils, watch or clock with second-hand, tape measure, rulers, calculators, student handouts

Prerequisite Knowledge for Students

- Using tape measures or rulers to measure distances
- Reading a second-hand on a watch or clock
- Converting a fraction to a decimal using long-hand or a calculator
- Rounding to the nearest ten-thousandths place (possibly with repeating decimals)
- Estimating
- Reading a table to determine the value of the glide slope
- Subtracting decimals
- Understanding the concept of the x-axis and y-axis
- Graphing a scatter plot and line of best fit



Materials

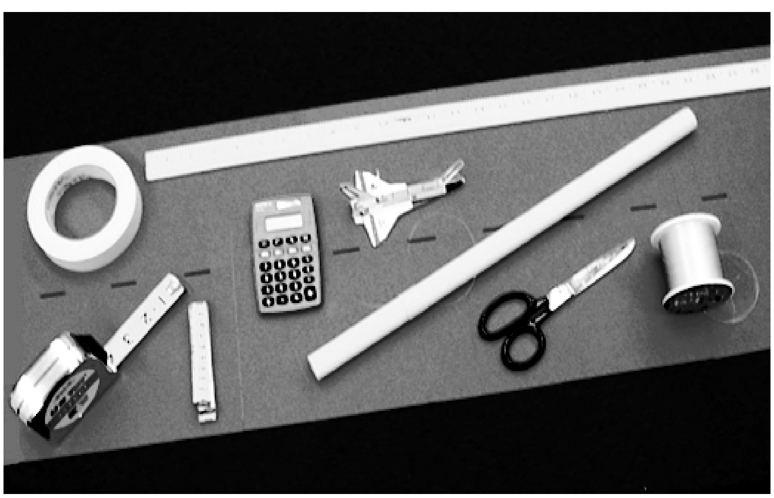
For each student:

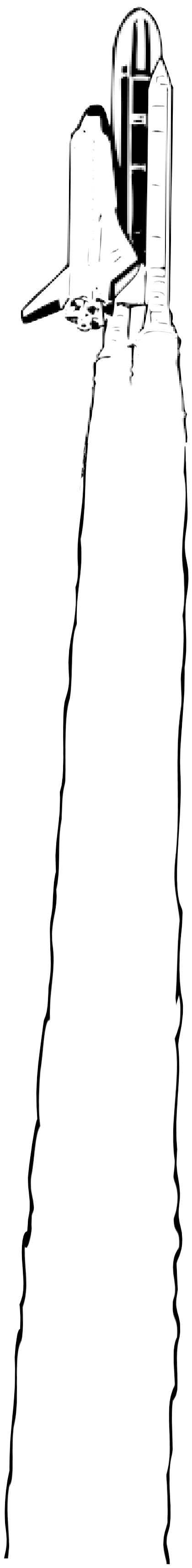
1. Student Handouts (see list in Teacher Overview Outline)
2. Space Shuttle Glider Kit -print from Web site on thick cardstock paper (65-80 lb. paper)

For each team (3-4 students per team)

1. Designate each team of students with a team name or number. (Idea: Use the names of NASA's shuttles: Columbia, Discovery, Atlantis, Endeavor and/or create names that would be appropriate for future shuttles: Explorer, Horizon, Revelation, Genesis, Voyager, Adventure, etc.)

2. Landing site:
   - fishing line
   - masking tape (that will not leave adhesive on the floor)
   - "control stick"
     (sawn off wooden broom handle, thick dowel, yardstick)
     optimum length: 1.5 feet (18 in.)
   - runway
   - tape measure or ruler
   - calculators
   - scissors
   - ladder or chair
     (without wheels) to stand on
   - space shuttle glider





Instructions for Building the Landing Site:

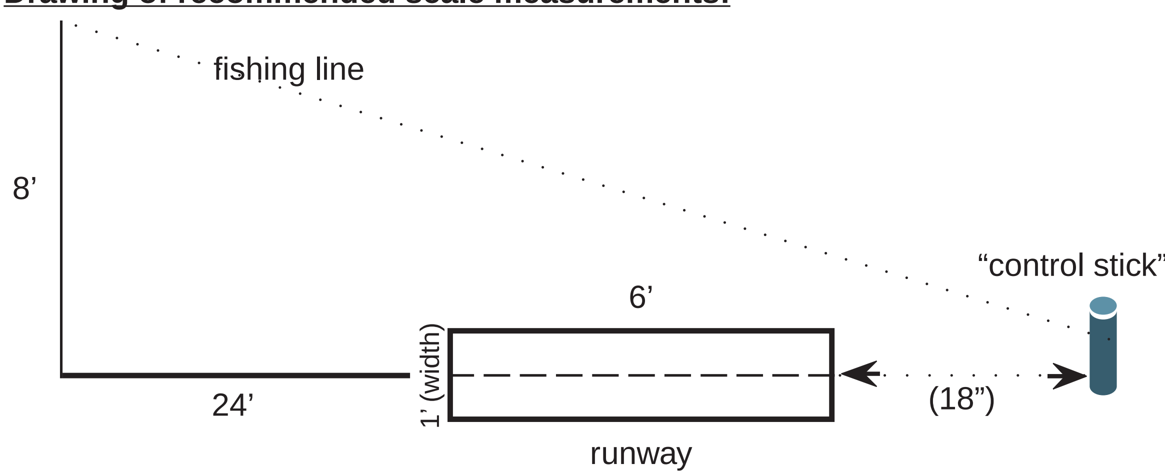
- The following suggested measurements used in this activity are as close as possible to a scale representation of the actual Space Shuttle.

- The measurements in the table, under “Space Shuttle Glider Activity-Teacher Information”, are the basis for the glider’s landing site measurements given below. The ratio of the Height of the orbiter compared to the Total distance to touchdown point is 1 to 3. Thus the measurements for the glider’s landing site, 8 feet high and 24 feet long, are also in a ratio of 1 to 3. If you are not able to appropriate this much space in your classroom, at least try to maintain the same ratio of 1 to 3.

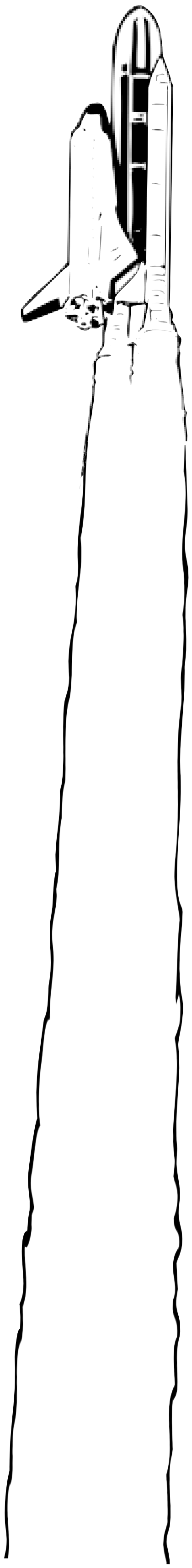
- The runway for the Space Shuttle Orbiter has measurements that are nearly twice the length of width of a conventional runway used for commercial airlines. The runway is 91 meters (300 feet) wide and 4,600 meters (15,000 feet) long. However, the orbiter aims for a point 1,500 meters passed the runway threshold, and usually rolls to a stop with 600 meters left. Thus the amount of runway that is actually used by the orbiter is 2,500 meters. The ratio of 91 meters to 2,500 meters is about 1 to 25. As you can see, the length of the runway is dramatically longer than the width of the runway. For our practical purposes, we found that a ratio of 1 to 6, although not to scale, is sufficient.

- For a wider, range of results, vary the measurements of each Landing Site, within the suggested parameters. You may want to try different ratios of 1 to 3. In other words, for the scatter plot worksheet, each group will have similar results if their landing sites have the same measurements.

Drawing of recommended scale measurements:



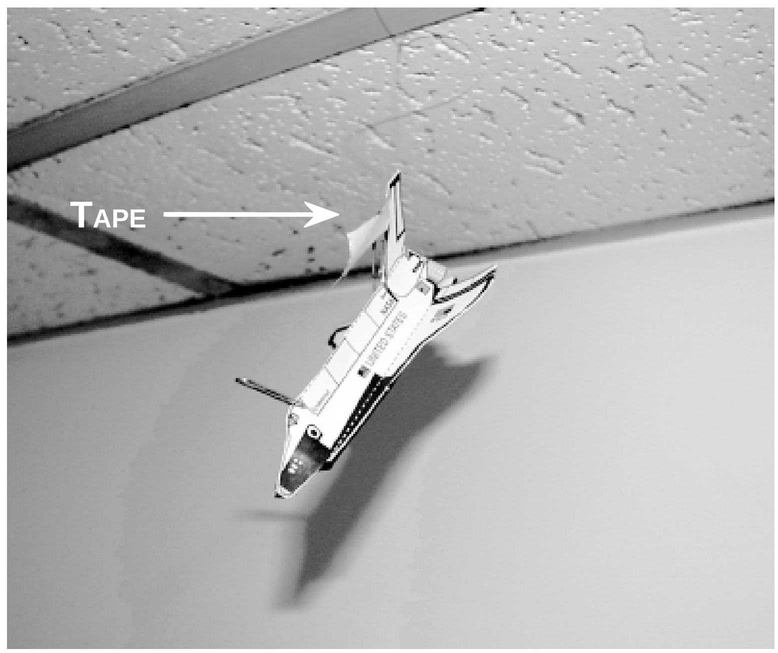
Note: Drawing itself is not to scale



a. Find a location that has about 30-35 feet in length of floor space, 3-5 feet in width and 8-10 feet in height.

b. Tie one end of nylon fishing line to someplace high, at least 7-8 feet high. (Suggestion: Try pinning a hook to your classroom wall, and looping the fishing line onto the hook.)

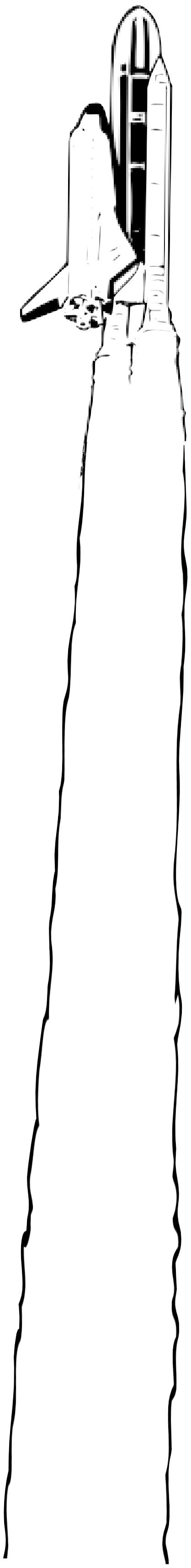
c. Wrap a piece of tape onto the fishing line at a point 3 inches away from where the top end of the fishing line is secured. This point is called the “measuring point”. The purpose of the tape is to hold the glider in place by “hooking” the paper clip over the tape to keep the glider from accidentally sliding down the fishing line.



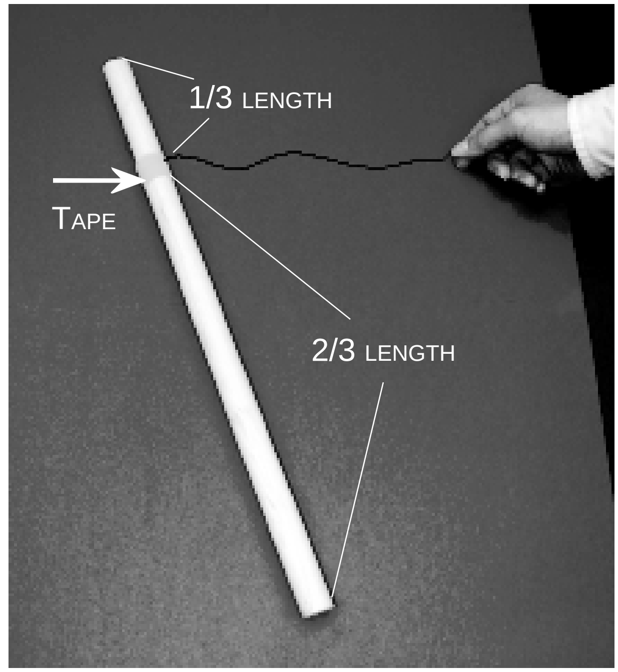
d. Run the fishing line to the end of the desired runway area.

e. Lay the fishing line along the ground to help you position the runway so that the fishing line runs down the center of it.

f. Place the tape on the ground to create the runway. Remember to keep an eye on the fishing line so that it runs down the center of the runway. (Another idea for creating a runway is to use construction paper, 12" x 9", and tape 8 sheets along the 12" side so that the finished runway is 12" x 72". Draw a dashed line down the center of the runway.)

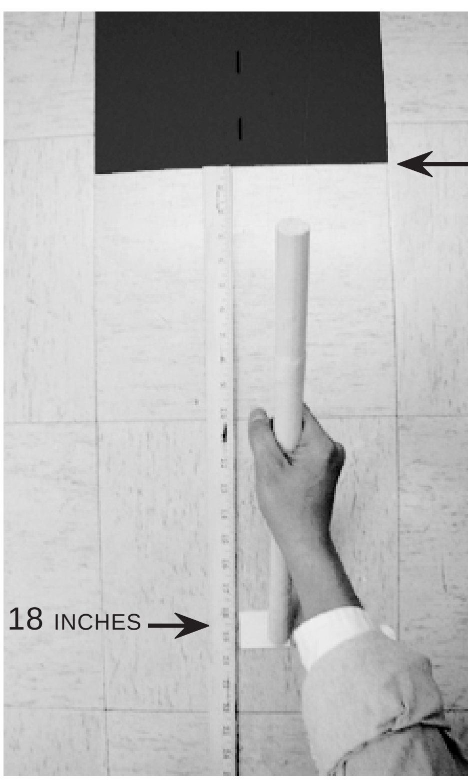


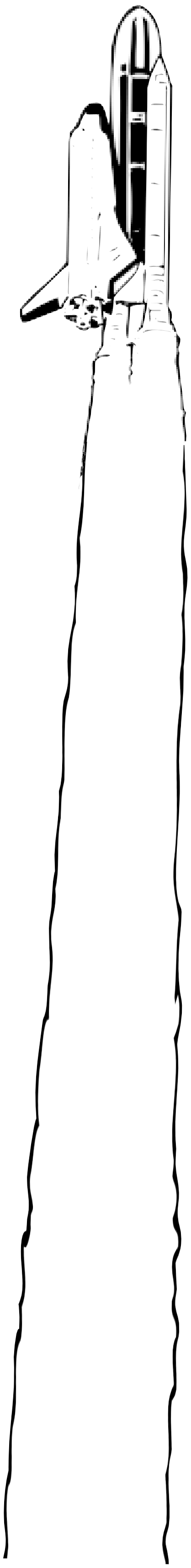
g. Make any necessary adjustments to the fishing line or the runway to make sure it is lined up.



h. Secure the fishing line onto the “control stick” about 2/3 of the length of the stick, from the bottom of the stick. For example, if your “control stick” is 18", the line should be tied 12" from the bottom of the stick. (Try tying the line around the stick then using a push pin, or tape to keep the line from sliding. Or cut a groove into the stick using scissors or an xacto knife to hold the line in place.)

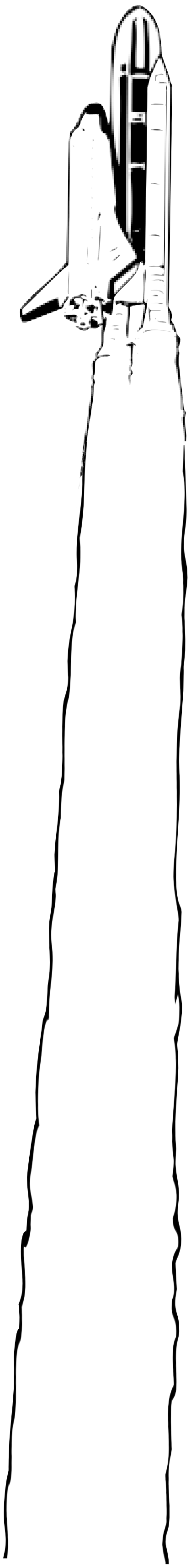
i. Place a piece of masking tape 18" past the end of the runway (on the opposite side from where the fishing line is tied to the higher end). This marks the spot where the pilot will place the bottom of the “control stick” when guiding the glider for landing. Be sure the fishing line can touch the runway, if the pilot leans the “control stick” forward.





j. Have the pilot sit down at the end of the runway with the stick held upright in front of him/her. Again, make sure the fishing line is running down the center of the runway.

k. Also check that the tension of the fishing line has enough slack to allow the glider to land on the runway. Otherwise the glider will fly right into the "control stick".



For each class

1. Large paper to display class results on scatter plot graph
2. Calculators
3. Glue (stick or white)
4. Tape (cellophane)
5. Masking tape
6. Paper clips
7. Fishing line
8. “Control sticks”
9. Tape measures or Rulers
10. Second-hand stop watches or Clock
11. Space Shuttle Glider Kit
12. Scissors
13. Pens or Pencils
14. Cardstock Paper (65 - 80 lbs.)
15. Double-sided tape
16. “Weight” (to attach to the bottom of the glider - see Step #11 in Instructions for Building Space Shuttle Glider)

Teacher’s Answer Key

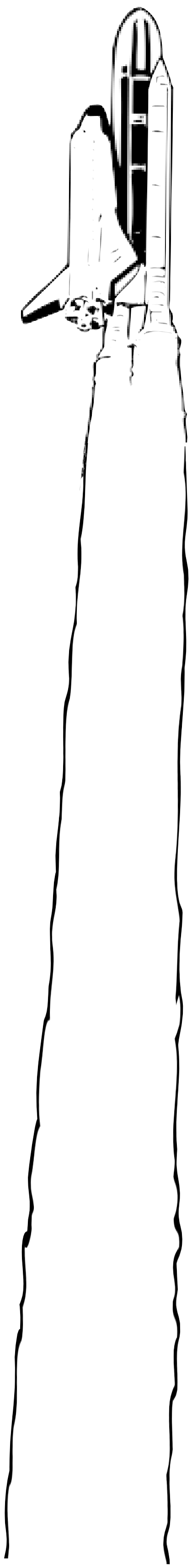
Answers for Math Worksheet of Prerequisite Knowledge

1. 36 inches
2. 66 inches
3. 30 seconds
4. 75 seconds
5. 0.5556
6. 0.5385
7. 36 degrees
8. 64 degrees
9. 45 degrees
10. 50 degrees

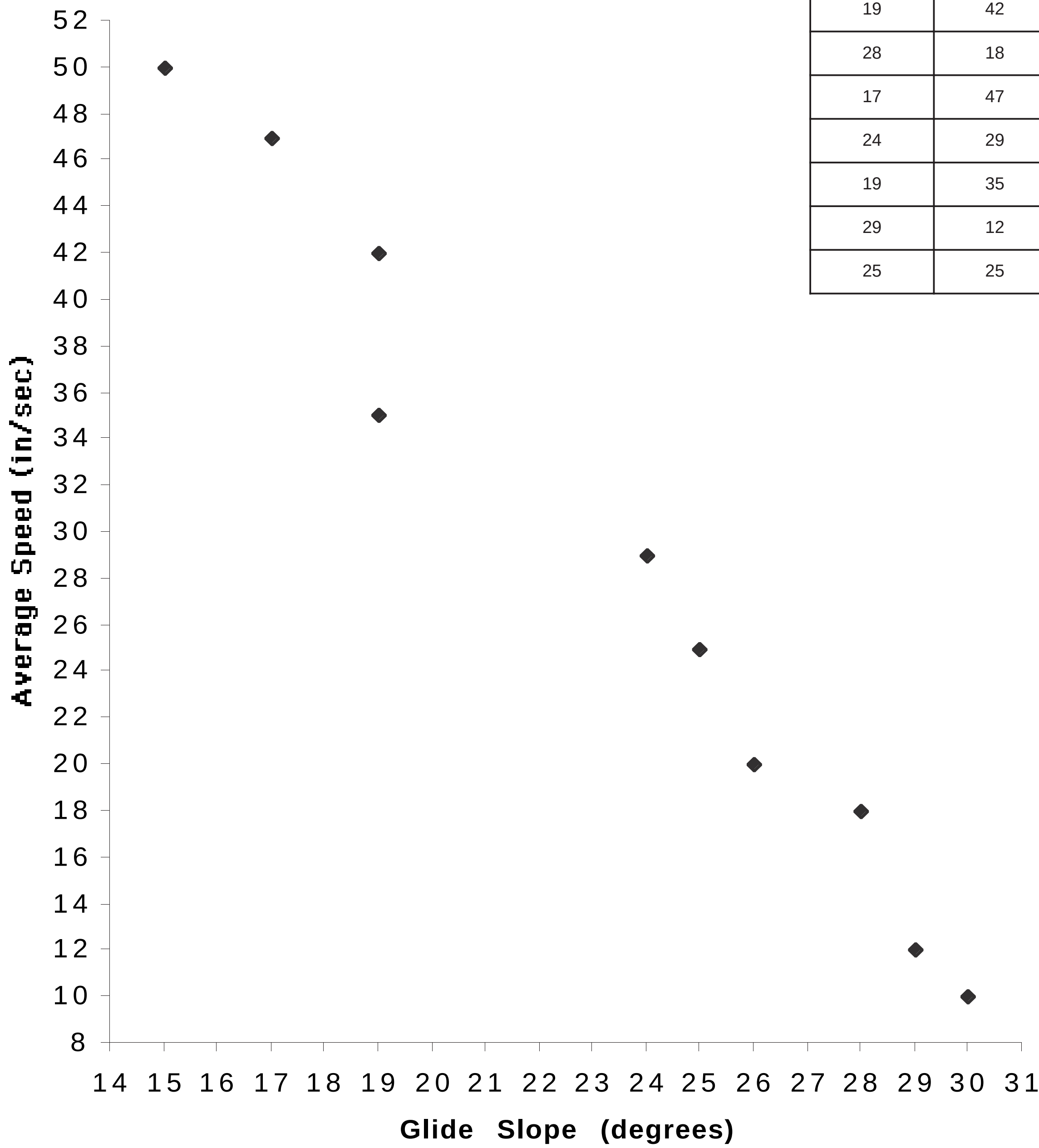
11. (on next page)

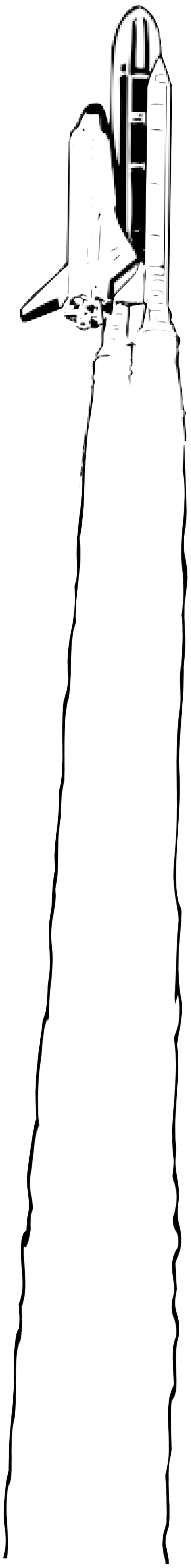
11.

<u>Relationship between Glide Slope and Average Speed</u>



Glide Slope	Average Speed
26	20
30	10
15	50
19	42
28	18
17	47
24	29
19	35
29	12
25	25





Answers for Practice Exercises on Computing Glide Slope

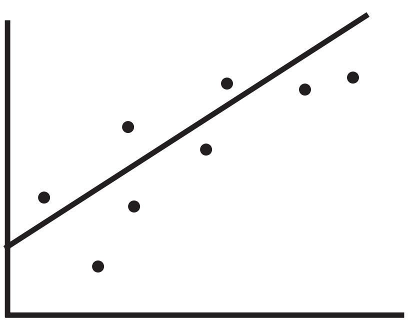
1. 62/92 = 0.6739 (closest to 0.6745, glide slope = **34** degrees)
2. 55/105 = 0.5238 (closest to 0.5317, glide slope = **28** degrees)
3. 73/90 = 0.8111 (closest to 0.8098, glide slope = **39** degrees)
4. 63/90 = 0.7000 (closest to 0.7002, glide slope = **35** degrees)

Answers for Practice Exercises on Computing Average Speed

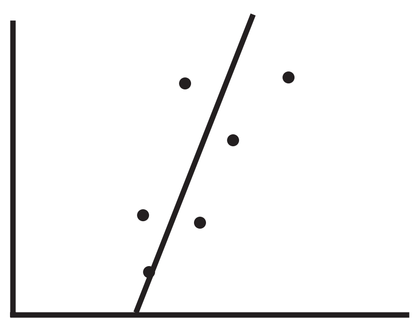
1. 92/10 = 9.2 in/sec
2. 80/6 = 13.33 in/sec
3. 75/8 = 9.38 in/sec
4. 77/9 = 8.56 in/sec

Possible Answers for Practice Exercises on Drawing a Line of Best Fit

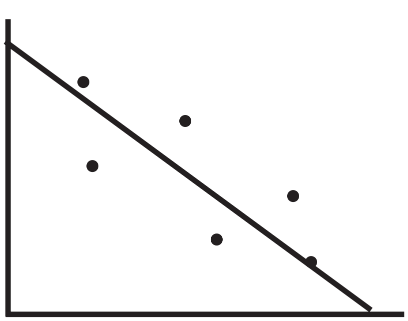
#1:



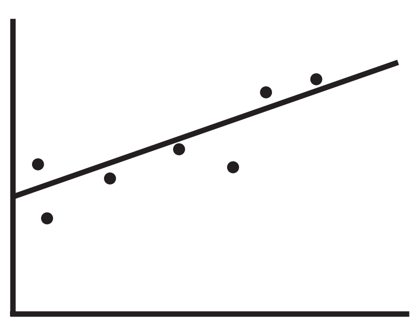
#2:



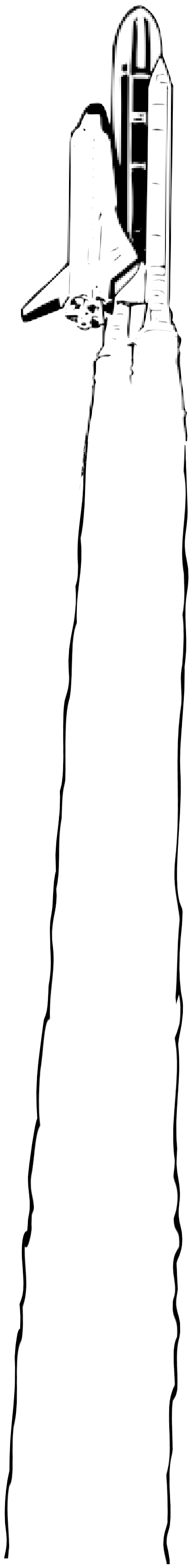
#3:



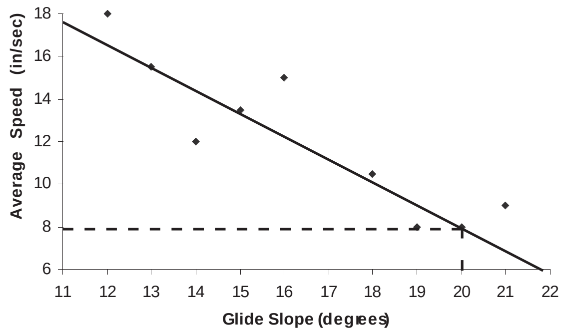
#4:



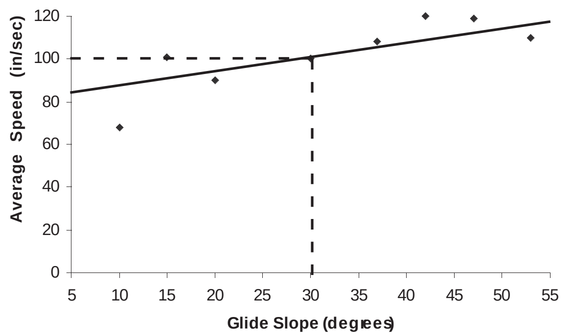
Answers for Practice Exercises on Using a Line of Best Fit for Making Predictions



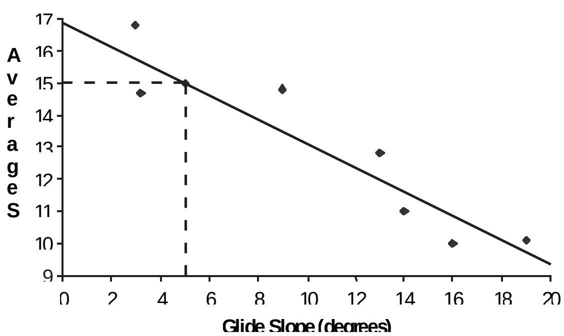
#1: If glide slope value = 20 degrees
Then, average speed = __8__ in/sec



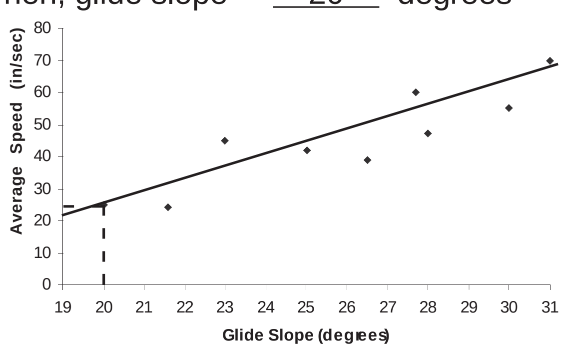
#2: If glide slope value = 30 degrees
Then, average speed= __100__ in/sec



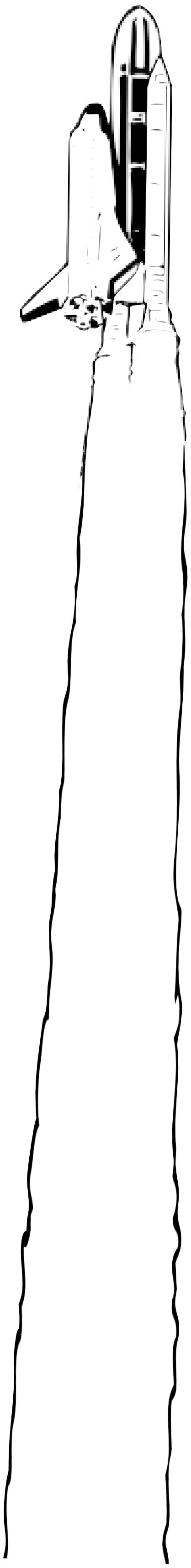
#3:If average speed = 15 in/sec
Then, glide slope = __5__ degrees



#4:If average speed= 25 in/sec
Then, glide slope = __20__ degrees

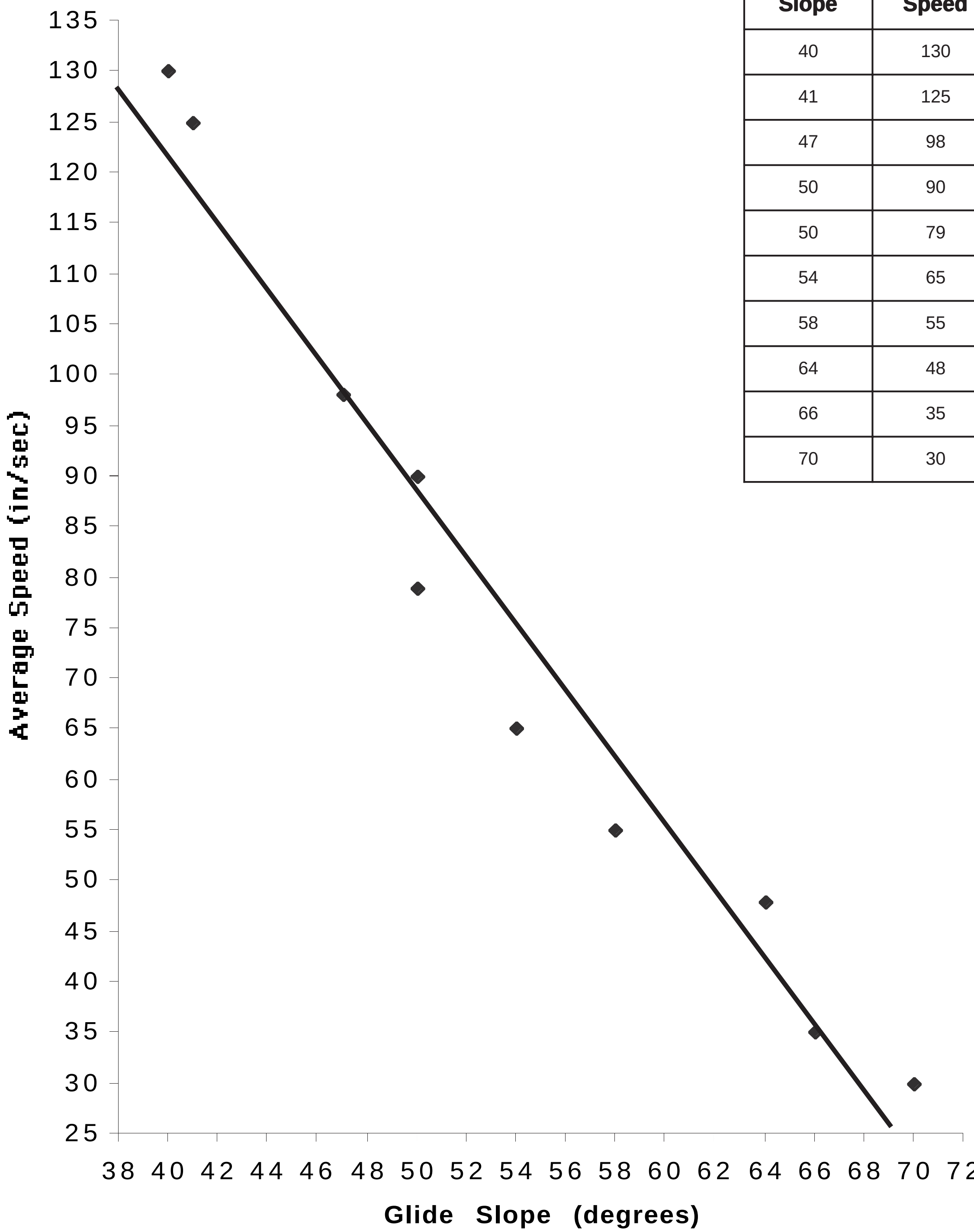


Answers for Practice Exercise on How to Create a Scatter Plot

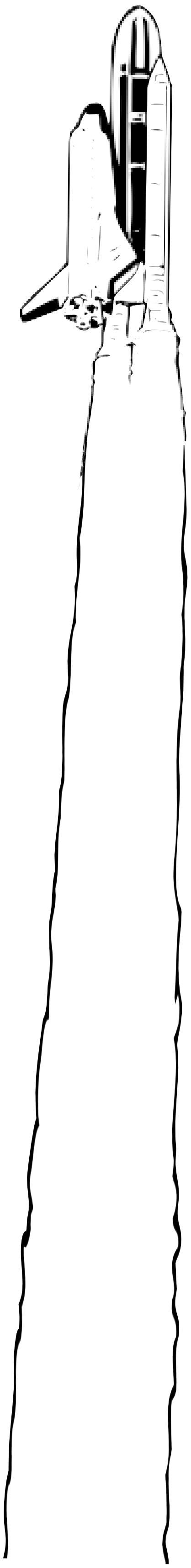


1.

Relationship between Glide Slope and Average Speed



Glide Slope	Average Speed
40	130
41	125
47	98
50	90
50	79
54	65
58	55
64	48
66	35
70	30



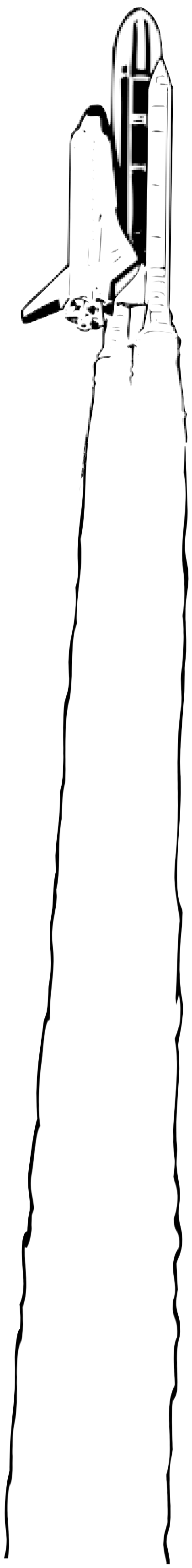
2. Negative Correlation

3. Answers may vary. Possible range of answers:

Glide Slope	Average Speed
44	(105 - 115)
52	(80 - 90)
60	(50 - 60)

4. Answers may vary. Possible range of answers:

Average Speed	Glide Slope
40	(64 - 66)
60	(58 - 60)
110	(42 - 46)



Classroom Activity

Session 1
Introduce your students to the unique qualities of the space shuttle orbiter. If possible, obtain a video clip ("Space Basics" video - http://quest.arc.nasa.gov/space/teachers/liftoff/basics.html), Web site, or other source that shows its reentry and landing. Be sure the students understand the reasoning behind the design of the orbiter and its unusual landing style. Go over the Student Reading found in the Student Handouts section.

Challenge students with the key questions and discuss:

- Why does the orbiter reenter the atmosphere at such a high velocity?
- Why is it necessary for the orbiter to reenter the atmosphere at such a steep angle of attack?
- What strategies does the orbiter take to slow down before landing?
- Does glide slope affect the speed of the glider?

Again using the Student Reading, have them discuss and compare some of the speeds and distances of the space shuttle to values that are more familiar to our lifestyles. Also review the Vocabulary List.

Session 2
Go over the necessary prerequisite math knowledge with students. Use the Math Worksheet, if appropriate.

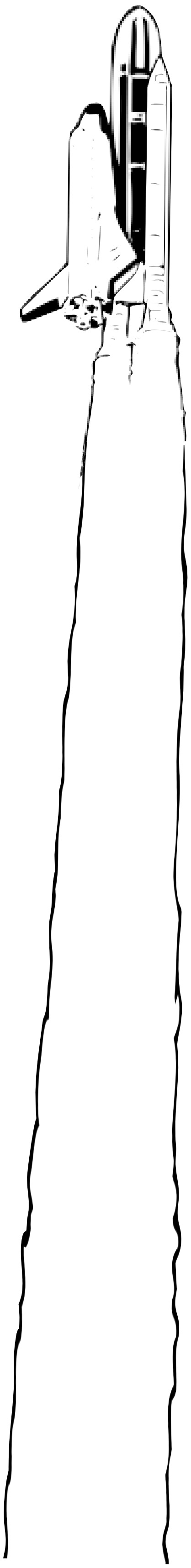
If time allows, explain to students the nature of the experiment with the shuttle glider so they know what to expect in the next two days. Show students a completed shuttle glider model and give them a sneak peek of the landing site.

Session 3
Assign students into teams of 3-4 people. Determine team names or numbers. Go over Team Members and their Roles.

Go over Space Shuttle Glider Activity - Student Information and Teacher Information

Go over Instructions for Building the Space Shuttle Glider.
Give students necessary materials (glider kit, glue, cellophane tape, paper clips, etc.) and the instruction sheet to build their gliders. Be sure each student has their name on their own glider, and remind them to puncture holes in the glider, before they glue or tape it together.

If students finish early, have them help you set up other landing sites around the room for Session 4's landings. (fishing line, sticks, masking tape)



Session 4
Go over Instructions for Landing Procedures.
Perform a trial run for your students so that they can see how the glider will “fly” on the fishing line. Try not to reveal the technique for being able to successfully land the glider. You may want to get a student to volunteer to be a “test pilot” for the first initial flight test.

Assign groups of 3-4 people. Hand out the Landing Data Collection Sheets (one per student) and have each student write their name in the **Pilot** box. Go over How to Compute Flight Time. Make other materials (tape measure, rulers, stop watches, calculators, etc.) available and allow them to perform their landings.

Session 5
Finish up Landings.

Go over How to Compute Glide Slope and How to Compute Average Speed. Hand out Table for Determining Glide Slope.

Session 6
Go over Purpose of Scatter Plot and How to Create a Scatter Plot

Hand out graph paper to allow each student to make their own scatter plot. Make a large class size graph and have each student plot their own point onto the graph. Place glide slope measurements on the x-axis and speed measurements on the y-axis.

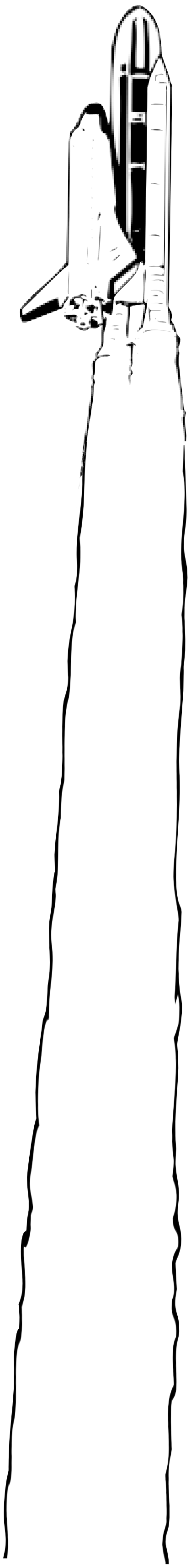
Session 7
Have each team of students share and discuss their group’s results.

- What did your group enjoy about this activity?
- What did your group find difficult about this activity?
- Name 2-3 things your group learned about the space shuttle that you did not know before.
- What were your glide slope angles? How did it affect the landings of the glider?

Discuss the results of the group as seen on the scatter plot. Is there a positive, a negative or no correlation between the two measurements? Have a student draw a line of best fit. Using this line, see if the students can:
- predict the speed of the glider given a glide slope.
- predict the glide slope given the speed of the glider.

If students finish early, change the flight distance (fishing line) either shorter or longer, or move the runway, either towards the high end or towards the “control stick”, to see if students can adjust the flight of the glider and still land successfully.

Glide Slope Activity: Student Handouts

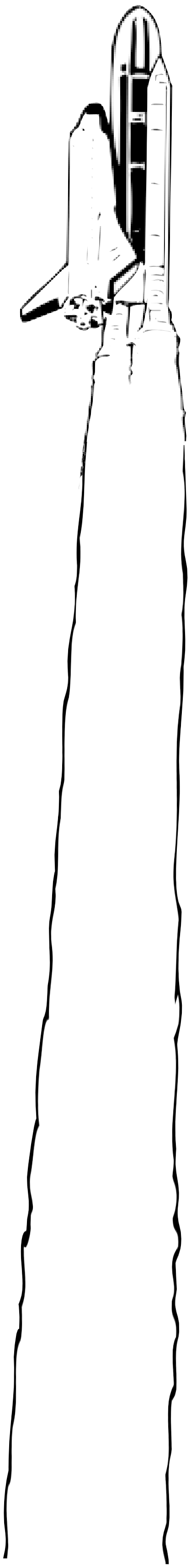


Contents:

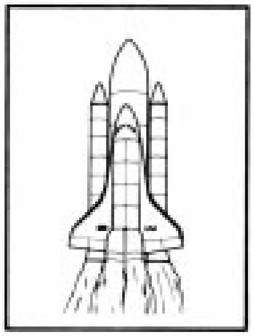
- Student Reading, with graphics, that explains the intricacies of Landing the Orbiter, Angle of Attack, and Glide Slope
- Vocabulary List
- Space Shuttle Glider Activity - Student Information
- Instructions for Building the Space Shuttle Glider
- Team Members and their Roles
- Instructions for Landing Procedures
- Landing Data Collection Sheet
- Math Worksheet of Prerequisite Knowledge
- How to Compute Glide Slope
- How to Compute Flight Time
- How to Compute Average Speed
- Table for Determining Glide Slope
- Purpose of a Scatter Plot
- How to Create a Scatter Plot

Student Reading

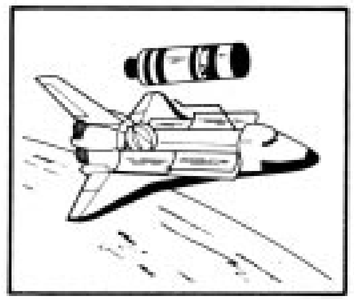
The Space Shuttle is a true aerospace vehicle:



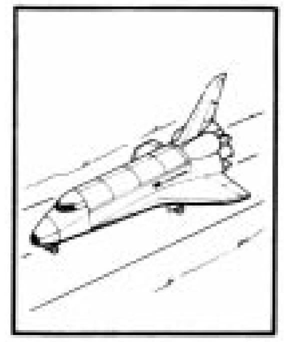
It launches like a rocket



It functions in orbit as a spacecraft



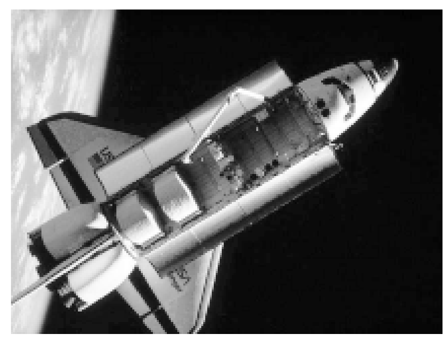
It lands like an airplane



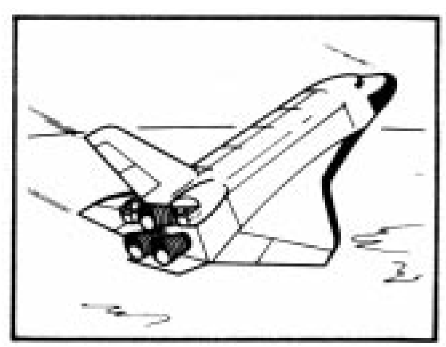
Landing the Orbiter

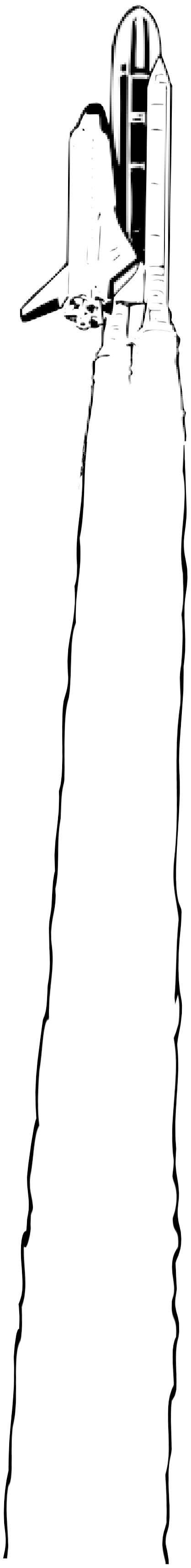
Landing the shuttle like an airplane begins 60 minutes prior to touchdown on the runway and is the final and most critical phase of the mission.

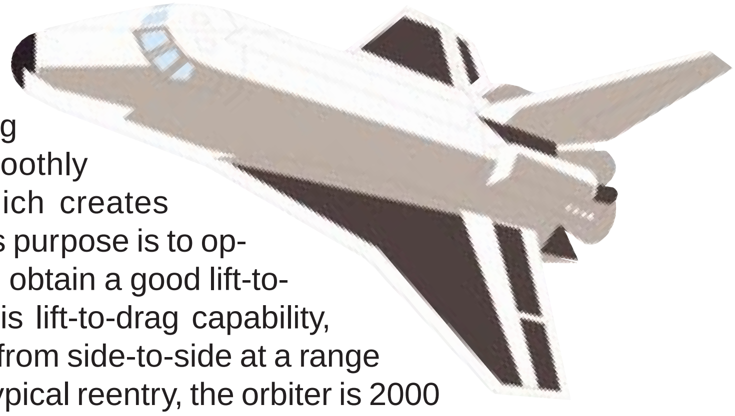
To examine this phase, let's begin the de-orbit process. The shuttle orbits the earth at a velocity of 27,000 km/hr.(That's over 17,000 mph! Race cars in the Daytona 500 speed race travel at "only" **230mph**.) Because the orbiter is traveling so fast, several things must be done in order to slow its descent and guide the orbiter safely back to earth.



One of things the orbiter does to slow itself down is to position the orbiter with its nose up at a high angle of attack and its travel-path at a glide slope between 28 to 38 degrees for reentry into the atmosphere. Because this brings the orbiter in belly-first, it increases drag as a wider surface is passing through all those air molecules. Imagine if you tried to sink a "boogie-board" (Styrofoam™ toy that floats on water) to the bottom of a swimming pool. It is much more difficult to sink the board if you tried to push it down belly-first, than if you tried to sink it on its side edge. This is the same concept that keeps the orbiter from landing at such a high speed.

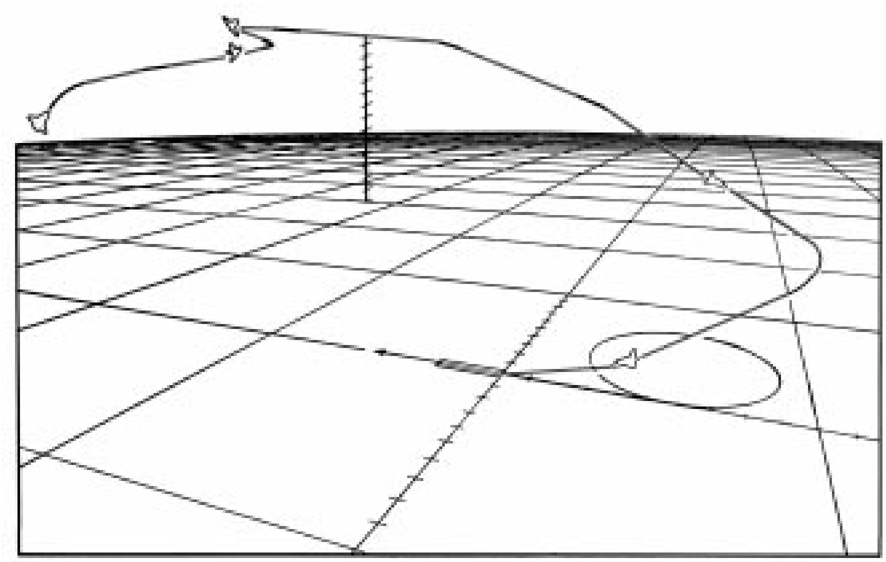




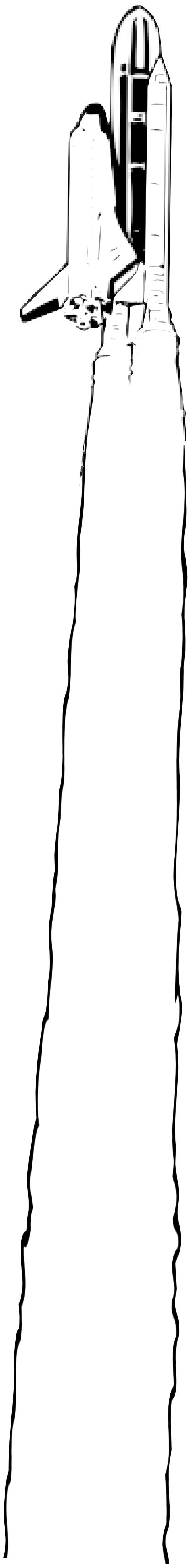


Secondly, the orbiter is designed with a double-delta wing configuration in which the forward placed delta wing creates vortices that flow smoothly over the main delta wing which creates greater lift and reduces drag. Its purpose is to optimize hypersonic flight and still obtain a good lift-to-drag ratio for landing. With this lift-to-drag capability, the orbiter is able to maneuver from side-to-side at a range of 2000 km (1240 miles). In a typical reentry, the orbiter is 2000 km away from the path of the runway and must fly, to its right, at its capacity range in order to position itself in line with the runway. This maneuver occurs 52 minutes before landing, with the shuttle at its maximum bank angle of 71 degrees.

The orbiter also performs a maneuver called a roll reversal, or S-turn. When the orbiter is 16 minutes away from touchdown, it begins its first of four S-turns which slows it down, just like a skier can slow down by making turns when coming downhill.



The rudder, which is on the tail of the orbiter, controls the yaw of the vehicle. The orbiter has a unique split-design rudder which allows it to also act as a speed brake. By pressing on both rudder pedals with both feet, the rudder “splits” open in a flat position just like a birthday card opens up. The rudder is opened to a full-out position ten minutes before the orbiter lands, but is soon adjusted to another position to provide assistance in directing yaw, as well as help reduce its speed.



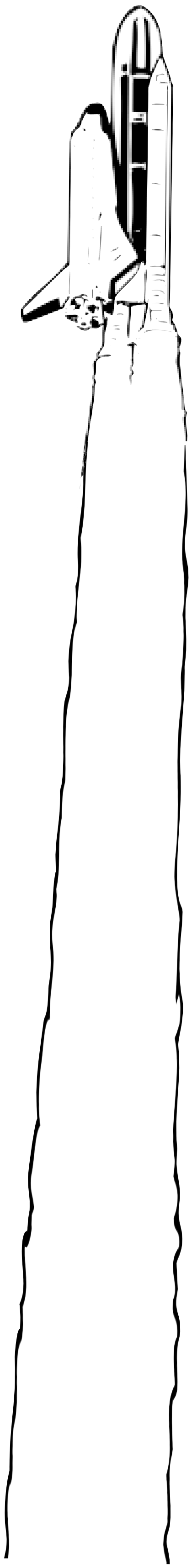
The shuttle is flying on auto-pilot for much of the descent, because the air is not thick enough for the orbiter's controls to be effective. But at 4 minutes before landing, the shuttle commander takes manual flight control of the spacecraft and keeps the orbiter in line with the center of the runway. The commander takes the orbiter out of the steep, 22 degree, glide slope by sharply pulling the nose up. This, flare maneuver, reduces the glide slope to 1.5 degrees (which is nearly parallel with the runway) with the nose pointed up. The pilot then lowers the landing gear at 27 meters (90 feet) off the runway. The landing gear creates a lot of drag and slows the orbiter down from 530 km/hr (330 mph) to 340 km/hr (215 mph). At this speed, the commander can land the orbiter at a safe speed. The speed at which the shuttle lands is typically two times faster than commercial airliners.

On touchdown, the orbiter activates its rudder once again to its full open position, and finally, the orbiter deploys a parachute to slow to a stop.

The accuracy of the landing is crucial because the orbiter lands like a glider does. It is not equipped with engines to give it thrust while flying in the Earth's atmosphere. Because it does not have engines like regular airplanes, the commander cannot abort a landing, give full thrust to the (non-existent) engines and circle the runway for another attempt. It has only one chance to land. Amazingly enough, the orbiter, which is traveling at such a high velocity, reenters the atmosphere at a point halfway around the world from its landing site. From this distant reentry, it is committed to its landing site.

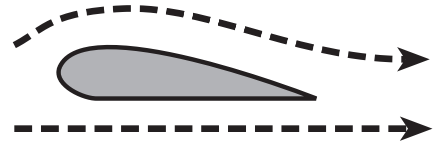
Angle of Attack

The picture shows the wing of an aircraft as it travels in a straight path parallel to the ground. The angle of attack refers to the angle between the wing and its flight direction.

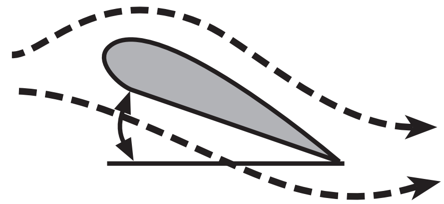


Angle of attack can change in two ways:

1. If the aircraft pitches its nose up or down, it will change its angle of attack. Imagine if you are holding your hand out the window of a moving car. The “flight” direction of the car is parallel to the ground just like in the picture. Now, if you were to hold your hand out flat so that your fingertips pointed into the wind, you could simulate the change in angle of attack by “pitching” your fingertips higher (towards the sky) or lower (towards the ground). You can also feel what an aircraft might feel when the angle of attack is changed, by how strong the wind is blowing on your hand, and where on your hand the wind is blowing.



0˚ angle of attack



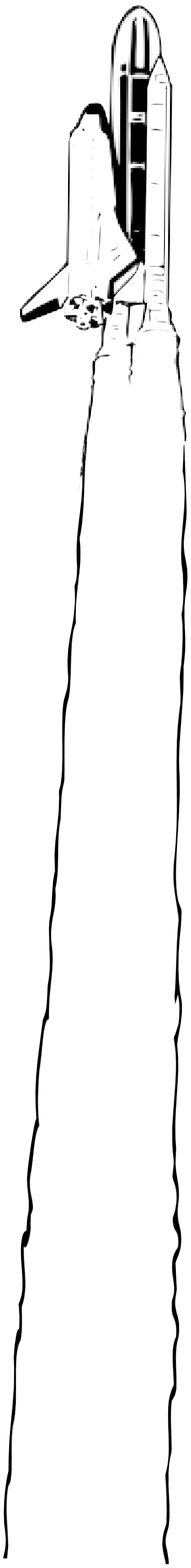
20˚ angle of attack

2. Now imagine you are on a roller coaster, and you are holding your hand out, just like you did in the car example, but, this time, don’t move the angle of your hand. The angle of attack is changing, even though your hand isn’t moving, because the direction of the roller coaster is changing. Sometimes, you are going in a steep climb, other times, you are steep drop, and then at other times, you are whizzing upside-down. Again, you can feel the effects of the changing angle of attack by the feel of wind on your hand.

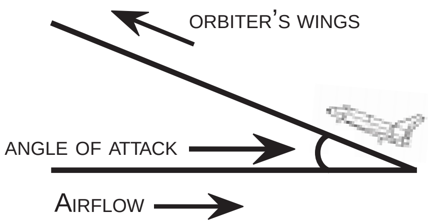
Glide Slope

The picture shows the shuttle as it approaches the runway for landing. Glide slope of the shuttle refers to the angle between the flight direction of the shuttle with respect to the ground. To understand glide slope, read this scenario: Imagine you are on a 3-meter high diving board (This is the typical size diving board found at local pools). Let’s say you were to dive, head-first, body completely straight, and with your arms out in front of your body. If someone were to take a picture of you the moment your hands hit the water, the angle your body makes with the water, would be the glide slope. In competition, divers try to enter the water at a 90 degree glide slope.

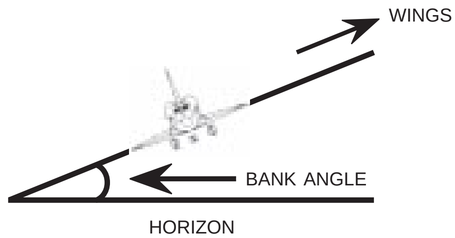
Vocabulary List



- **angle of attack** - the angle of the orbiter's wings to the oncoming airflow.

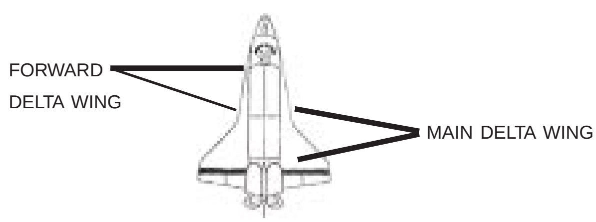


- **bank angle** - (roll) the angle between the wings and the horizon.



- **drag** - the force that resists the motion of the aircraft through the air, friction.

- **double delta wing** - a wing design that combines a forward placed delta wing with a main delta wing. The forward placed delta wing creates vortices that flow smoothly over the main delta wing, which creates greater lift and reduces drag.



- **glide slope** - the angle at which the orbiter descends with respect to the ground.

- **hypersonic flight** - refers to speeds above Mach 5 - five times the speed of sound.

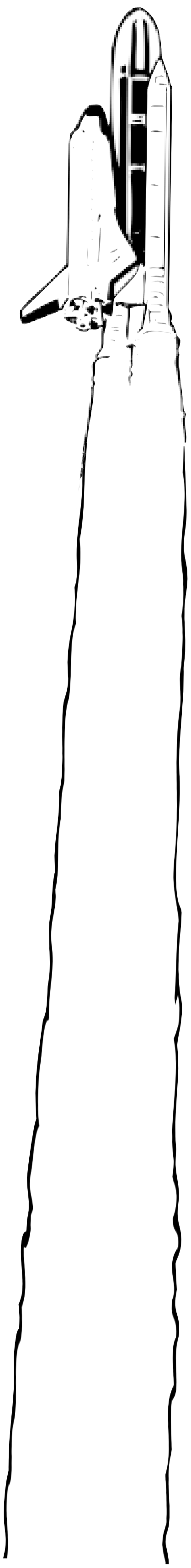
- **lift** - upward force produced by air passing over and under the wing of an airplane.

- **orbit** - the circular path of the shuttle in space, around the Earth.

- **Mach** - term used to describe the speed of objects relative to the speed of sound.

- **Mach 1** - the speed of sound; approximately 1226km/hr (762 mi/hr).

- **unit rate** - a ratio written as a fraction comparing two different values, the value in the denominator is always 1. (examples: 55 miles/ 1 hour or $.99/ 1 pound.



Space Shuttle Glider Activity - Student Information

1. You are to construct a space shuttle glider which is reduced to a scale of 1cm:300cm compared to the actual U.S. Space Shuttle orbiter. There are Instructions for Building the Space Shuttle Glider that will guide you step-by-step through the process.

2. You will be assigned to a team of 3 or 4 people where you will rotate positions as the pilot, copilot, Mission Control Center, and Mission Specialist for each landing. Find out what each person does on the Team Members and their Roles Sheet.

3. Using a constructed landing site, you will re-enact the landing procedure. Remember to take turns being the pilot, copilot, Mission Control Center, and Mission Specialist. If you have only 3 people in your group, the Mission Control Center will be the Mission Specialist at the same time.

4. When you are the Mission Specialist, be sure you have the **pilot's** Landing Data Collection Sheet. You are in charge of recording the data for the pilot on his/her Landing Data Collection Sheet.

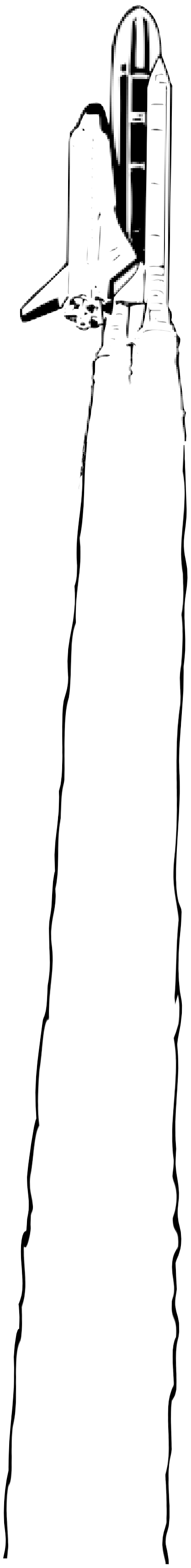
5. When you are the pilot, be sure to give your Landing Data Collection Sheet to the Mission Specialist.

6. There is a Handout called **Math Worksheet of Prerequisite Knowledge** that each team member must complete. It will assist you in completing the Landing Data Collection Sheet.

7. There are other aids to help you complete the Landing Data Collection Sheet:
   - How to Compute Glide Slope
   - How to Compute Flight Time
   - How to Compute Average Speed
   - Table for Determining Glide Slope

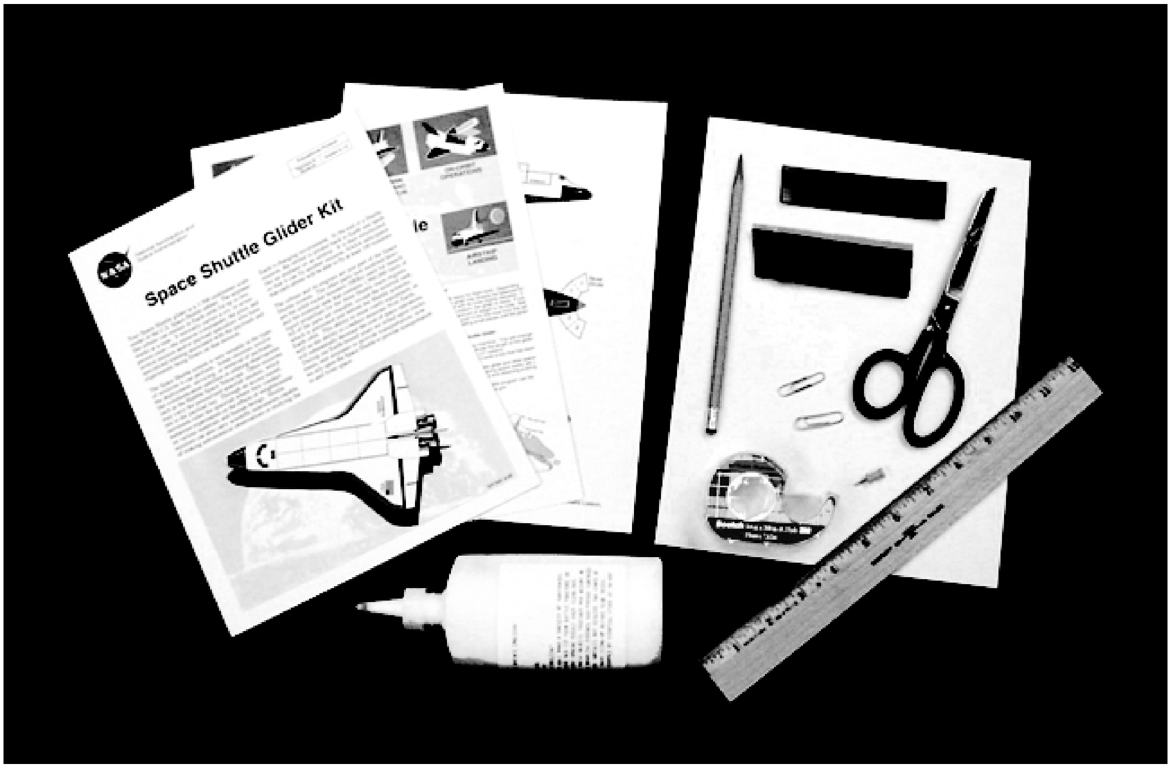
8. After you've completed the Landing Data Collection Sheet, you will use your numbers for the Glide Slope and Average Speed to create a scatter plot. There are two handouts to help you:
   - Purpose of a Scatter Plot
   - How to Create a Scatter Plot

9. Finally, your group will have the opportunity to share your results with the class and help create a class-wide scatter plot.

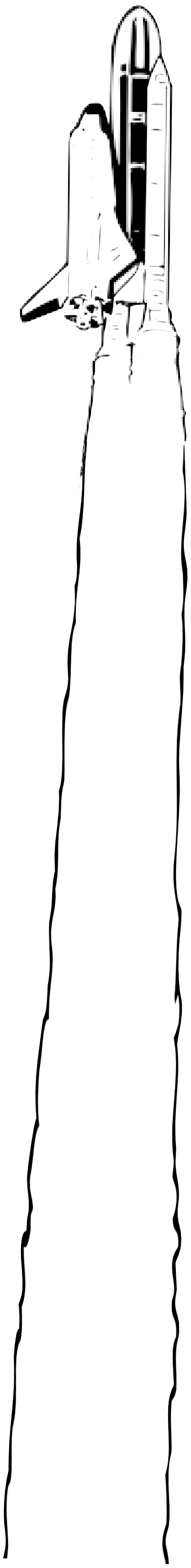


Instructions for Building the Space Shuttle Glider:

Materials needed:



- Space Shuttle Glider Kit printed on cardstock (65-80 lbs.)
- Pen or Pencil
- Scissors
- Rulers
- Glue (stick or white)
- Tape (cellophane)
- Double-sided tape
- “Weight” (heavy/thick paper, heavy cardboard, flat magnet etc. approximately 0.6 oz)
- 2 small paper clips per glider



1. Before cutting, write your name in any of the empty rectangles near the “flaps”.

2. Using scissors, cut out the entire pattern on the outside lines. (Do not cut along the dashed lines.) The more careful you are cutting, the better the finished glider will look.

3. Line up the ruler with the dashed fold lines. Use the edge of another ruler to press a groove into the lines. This will make folding more accurate.

4. After creasing all folds in the glider, line up the 2 top pieces side to side and use a push pin to puncture a hole near the cockpit windows. Making sure that the flaps are folded inside the glider, puncture another hole through the last rectangle (that has the word NASA in it) so that it goes through the flap to the other side.

5. Fold the paper on all dashed lines. The dashed lines will be up for a mountain fold and down for a valley fold.

6. Lightly cover both pieces of nose strut 1 with glue. Fold it over the nose of the glider to form a triangle shape. Bend nose strut 2 over and press to strut 1 until the glue holds.

7. Coat the inside of each wing with glue and press top and bottom together. Be very careful to line up the parts.

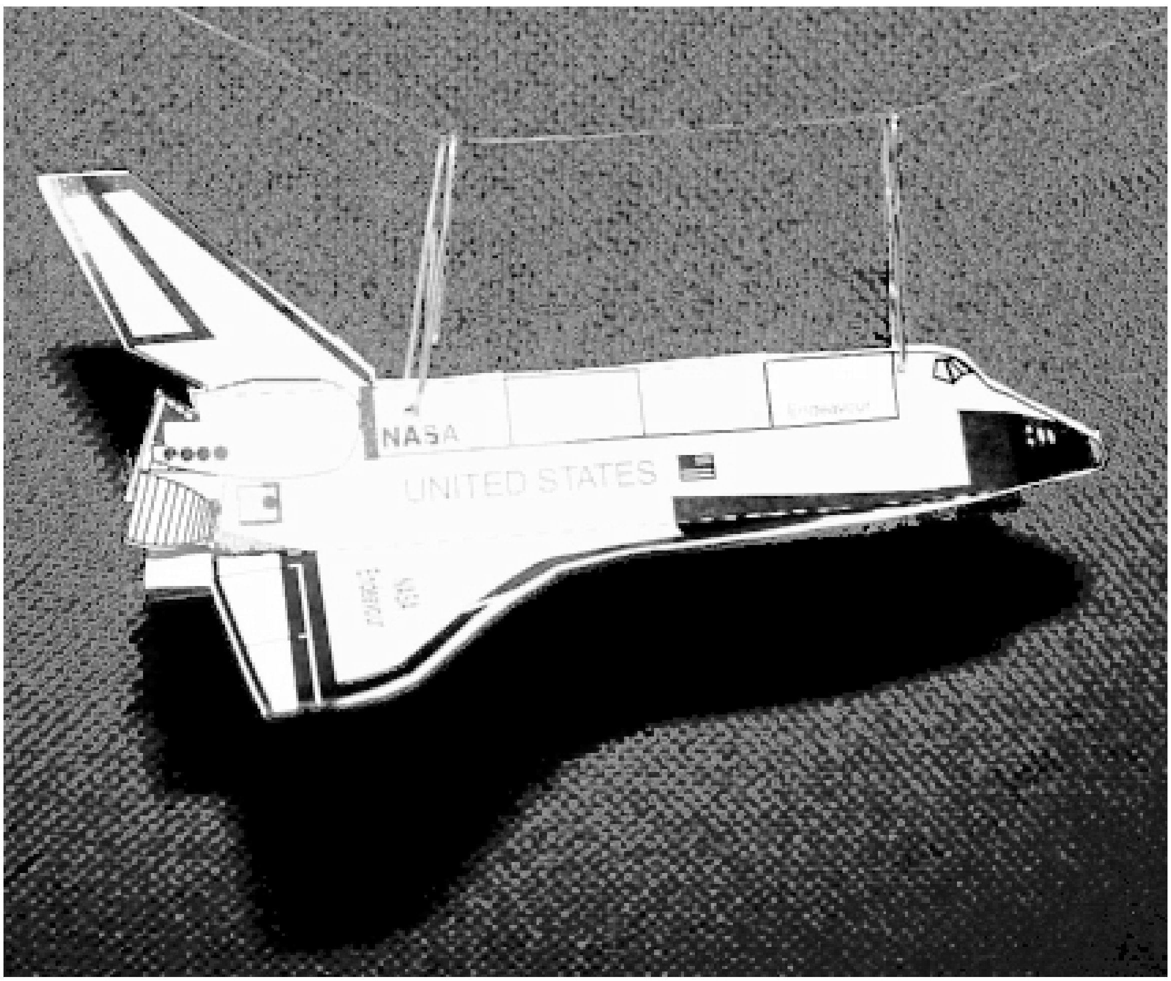
8. Coat the inside of the tail pieces with glue. Also coat the outside of the four flaps along the payload bay with glue. Bring the two sides of the payload bay together so that all flaps slide **inside** the glider. Lightly press the payload bay and the tail pieces together until the glue holds.

9. Coat the inside surface of the nose on each side with glue and press them to the struts until the glue holds. If you wish, strengthen the nose with a small amount of cellophane tape.

10. Put a small amount of glue on the inside of the tiny triangle at the nose of the glider. Bend it upward to close the hole. As the glue dries, the triangle will stay put.

11. Glue or use Double-sided tape to attach a “weight” to the bottom of the orbiter. A weight of approximately 0.6 oz is recommended when using the suggested landing site parameters. Some ideas for weights include (heavy/thick paper, heavy cardboard, flat magnets, or anything heavy enough, but still flat enough so that it does not produce too much drag). This weight is needed to give the shuttle enough momentum to reach the runway without “stalling” on the fishing line.

12. Hook a small paper clip into each of the holes in the glider.

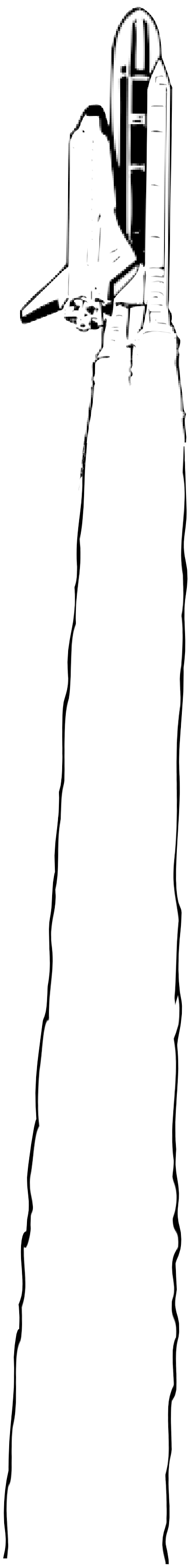


<u>Team Members and their Roles</u>: (pilot, copilot, Mission Control Center, and mission specialist) If there is a group with only 3 people, have one person be both Mission Control Center and the mission specialist.

- Pilot - The pilot sits at the end of the runway and holds the "control stick" to position the fishing line so that it is centered down the middle of the runway. It is also necessary to cooperate with the copilot in checking the fishing line connections at both the "control stick" end and the higher end, as well as the tension of the fishing line. The pilot maneuvers the "control stick" to guide the glider in for a smooth landing.

- Copilot - The copilot is in charge of preparing the glider for flight. This person should cooperate with the pilot in checking the fishing line connections at both the "control stick" end and the higher end as well as checking the tension of the fishing line.

After "hooking" the paper clip, from the glider onto the fishing line at the "measuring point", the copilot holds the top end of the tape measure or ruler at the tip of the glider's nose, so that the mission specialist can find the Height of the Glider from the ground. Once measurements have been taken, the copilot continues to hold the glider at the "measuring point" until given clearance from Mission Control Center to unhook the glider for landing.



<u>Team Members and their Roles</u>: (continued)

- Mission Control Center (MCC) - This person must double check everyone's duties:
    - be sure the pilot
        - is positioned correctly
        - has checked the fishing line connections and tension
        - is prepared to "fly" the glider

    - be sure the copilot
        - has checked the fishing line connections and the tension
        - has correctly prepared the glider for flight

    - be sure the mission specialist
        - has the necessary equipment to collect data on glide slope, flight time, and flight distance

    Mission Control Center is the only person who can give the clearance signal - "cleared to land" - that allows the copilot and pilot to initiate the landing sequence. (The clearance signal could be a countdown such as "3-2-1-Cleared for Landing!" or simply "Ready-Set-Go!")

- Mission Specialist - This person has the duty of recording the data from the flight. Data must be collected on:
    - Height of glider from ground (using tape measure or yardstick)
    - Total distance to touchdown point (using tape measure or yardstick)
    - Slope (using calculator to determine decimal equivalent
    - Glide Slope (using Table for Determining Glide Slope)
    - Flight Time (using watch or clock with second-hand)
    - Speed (using data from Total Distance and Flight Time)

    Be sure the specialist has a pencil and the Landing Data Collection Sheet.

Each team member is responsible for:

- Reading the Student Reading
- Reading the Vocabulary List
- Building the glider
- Knowing the responsibilities of each different position
- Assisting in the landing procedure
- Completing the Math Worksheet of Prerequisite Knowledge
- Helping to compute glide slope, flight time, and speed
- Creating the scatter plot
- Helping to clean-up

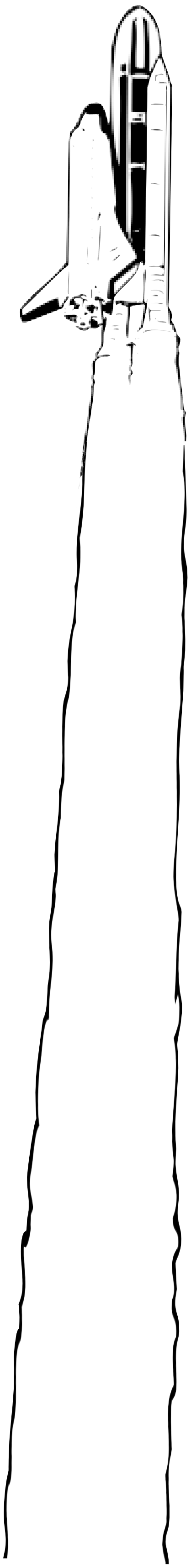
Instructions for Landing Procedures:

1. The copilot “clips” the glider onto the fishing line (from the high end) and positions the glider at the “measuring point” until Mission Control gives the clearance signal.

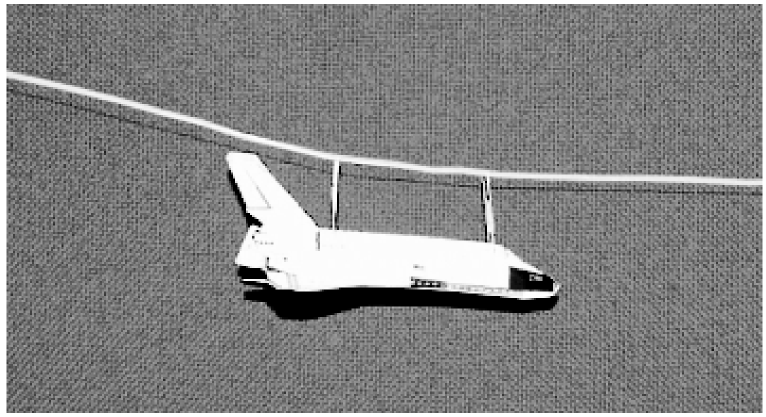
2. The pilot holds the “control stick” upright with one end on the floor, so that the fishing line is running down the center of the runway. Make any necessary adjustments so that the fishing line and the center of the runway are lined up, and so that the fishing line has enough slack to allow the glider to land on the runway and not glide into the “control stick”.

3. Once the copilot and pilot are in position, the mission specialist and Mission Control Center will begin taking measurements (see “How to Compute Glide Slope”). The mission specialist must be ready with the Landing Data Collection Sheet and equipment (pencil, tape measure or ruler, second hand watch, calculator).

4. Mission Control Center watches over the pilot, copilot, and the mission specialist to make sure everyone is properly set-up and ready before giving the clearance signal. (The clearance signal could be a countdown such as “3-2-1 Cleared for Landing!” or simply “Ready-Set-Go!”)



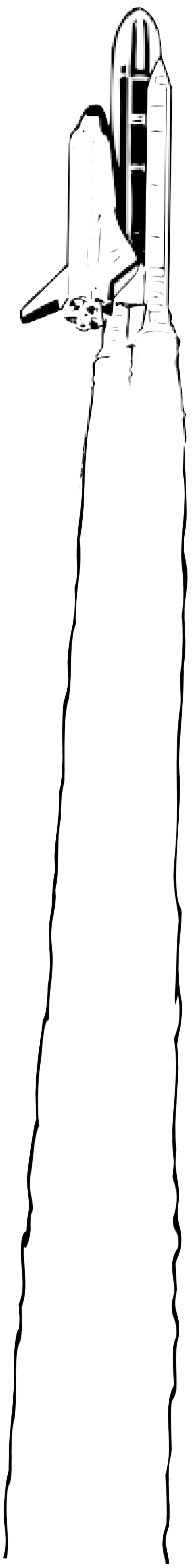
5. Once Mission Control Center gives the clearance signal, the copilot releases the glider. The glider starts its descent as it zooms down the fishing line toward the pilot.



Please Note: Fishing line has been "enhanced" in this picture so that it can be seen.

6. At the moment the copilot releases the glider, the mission specialist must be watching the second-hand of a watch or clock to begin timing the number of seconds the glider is in motion. When the glider comes to a complete stop, the mission specialist should record the Flight Time (in seconds) on the Landing Data Collection Sheet.

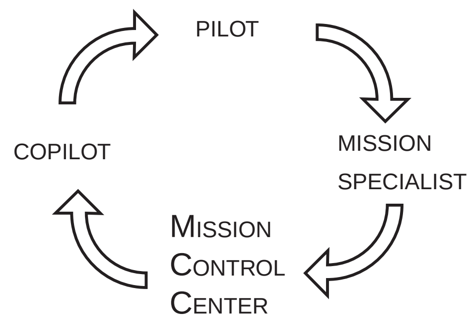
7. The pilot must control the glider's flight path and speed with the "control stick" to make it land on the runway. A successful landing is defined as the pilot smoothly landing the glider on the centerline of the runway.



8. If the landing is successful, have the mission specialist record all the data, then have everyone rotate positions to experience the landing from another viewpoint.

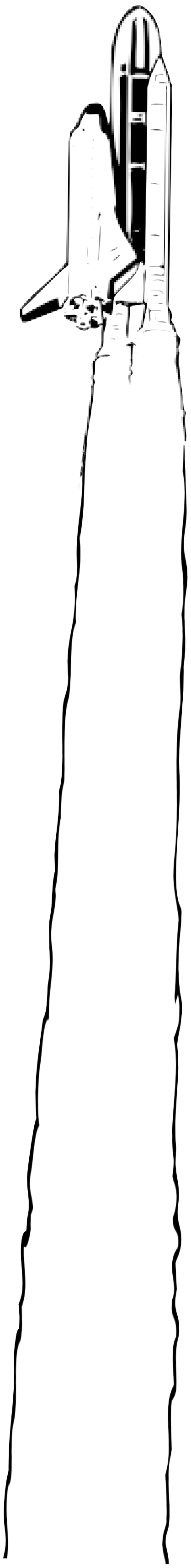
9. If the landing is unsuccessful, reset the glider and allow the pilot another chance to land the glider. The mission specialist should not record the data unless the landing is a successful one.

10. The positions should rotate in this order:
    - pilot to mission specialist
    - copilot to pilot
    - Mission Control Center to copilot
    - Mission specialist to Mission Control Center



11. The “new” mission specialist will need to use the “new” pilot’s Landing Data Collection Sheet to record the next set of data.

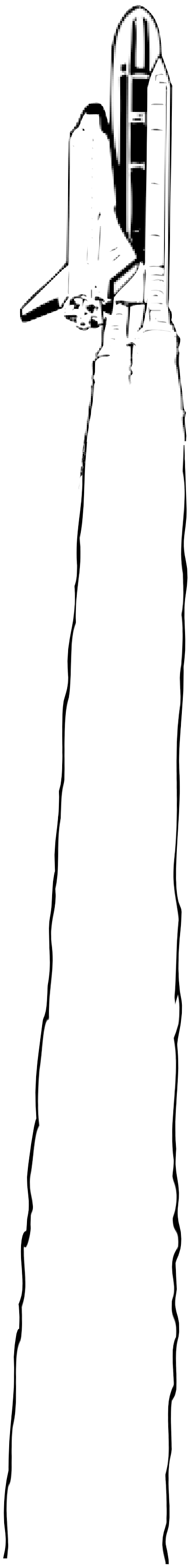
Landing Data Collection Sheet



For the Mission Specialist : Please fill in the left column with Team name (or number) and with names of the pilot, copilot, Mission Control Center, and Mission Specialist.

Be sure to write in all measurements and calculations listed below.

Team ______________	Height of glider from ground parallel to **y-axis** (inches) ______________
Pilot ______________	Total distance to touchdown point along **x-axis** (inches) ______________ (measure distance on the ground)
Copilot ______________	Slope = --------- = ----------- (fraction) ________
Mission Control Center ______________	Glide Slope (use table) ______________
Mission Specialist ______________	Flight Time (in seconds) ______________
	Average Speed: Total Distance / Flight Time (in inches / second) ______________



Math Worksheet of Prerequisite Knowledge

Round answers to the nearest hundredths place, when necessary.

1. Convert 3 feet into ________ inches.

2. Convert 5.5 feet into ________ inches.

3. Convert 0.5 minute into ________ seconds.

4. Convert 1.25 minutes into ________ seconds.

Round answers to the nearest ten-thousandths place.

5. Convert 5/9 into a decimal. ________

6. Convert 7/13 into a decimal.________

Use the Table for Determining Glide Slope.

7. Find the glide slope for 0.7265: ________

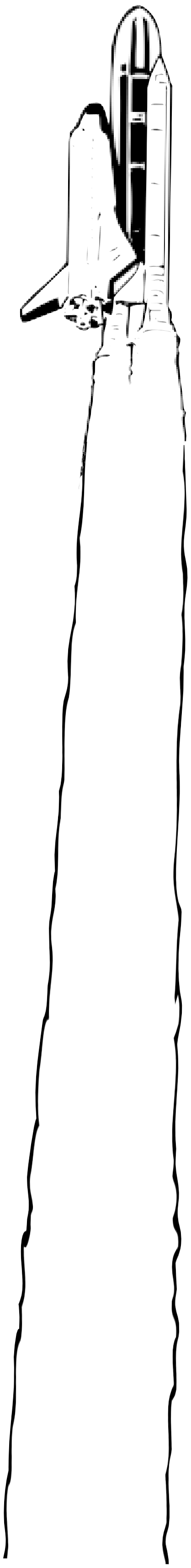
8. Find the glide slope for 2.0503: ________

9. Estimate and subtract to find the glide slope for 0.9899: ________

10. Estimate and subtract to find the glide slope for 1.2058: ________

11. Create a Scatter Plot for the following data:

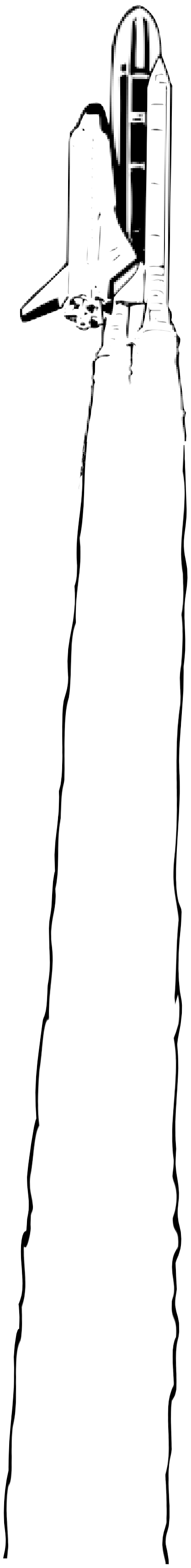
Relationship between Glide Slope and Average Speed



Glide Slope	Average Speed
26	20
30	10
15	50
19	42
28	18
17	47
24	29
19	35
29	12
25	25

AVERAGE SPEED (IN. /SEC.)

GLIDE SLOPE (DEGREES)

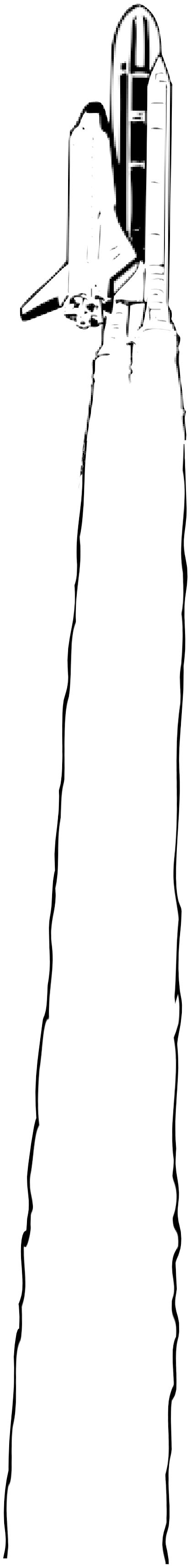


<u>How to Compute Glide Slope</u>

1. Have the pilot hold “his/her” end of the fishing line with even tension (no slack in fishing line) at the desired touchdown point on the runway (on the ground).

2. At the “measuring point”, have the copilot hold a tape measure or ruler to find the height of the glider, (from the glider’s nose) to the ground in inches. The mission specialist should hold the tape measure or ruler on the ground so that it is vertical, and not slanted to the side. (Imagine you are measuring your own height, you want to stand up <u>straight</u> and tall to get the correct measurement. Ask Mission Control Center to stand about 5 feet away and “eyeball” the tape measure from the front view and from the side view to make sure it is vertical.)

3. Before writing the measurement down, put a piece of tape (like the one used to make the runway) at the place where the tape measure or ruler touches the ground. (This is the starting point for measuring the glider’s horizontal distance.) Now write your measurement down as the Height of Glider, on the Landing Data Collection Sheet.



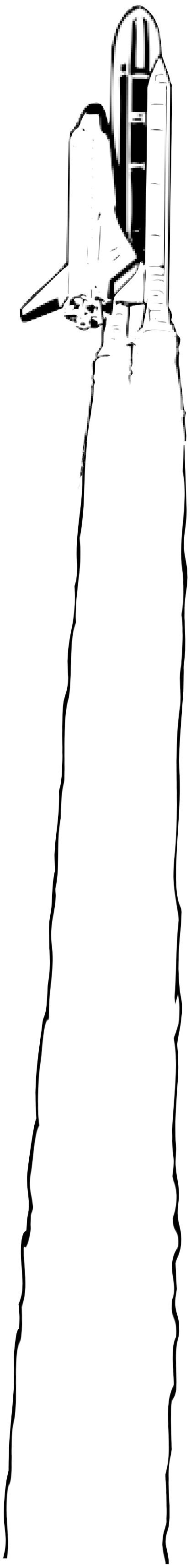
4. To find the glider's horizontal distance to the approximate touchdown point in inches, have Mission Control Center hold the top end of the tape measure or ruler at the place where you put the piece of tape on the ground. Measure the distance to where the pilot is holding the end of the fishing line (attached to the "control stick") on the ground. Make sure the fishing line has an even tension (no slack in fishing line). And also check to see if the pilot is holding the fishing line in the center of the runway. Write this measurement as the Total Distance to the touchdown point on the Landing Data Collection Sheet.

5. Write a fraction using the **y-axis** value as the numerator and the **x-axis** value as the denominator. (Both of these values should already be written on the Landing Data Collection Sheet.) Write this fraction as the **slope** on the Landing Data Collection Sheet.

6. Find the decimal equivalent to the fraction by dividing the denominator **in to** the numerator. If necessary, round the decimal to the nearest ten-thousandths place. Write this decimal number next to the fraction on the Landing Data Collection Sheet.

7. Find this number, or the number **closest** to it, in the left column of the "Table for Determining Glide Slope". (See below for example on how to determine which number is the **closest**.)

8. The number, in the right column, that corresponds with the decimal number is the glide slope. Write this number as the **Glide Slope** on the Landing Data Collection Sheet.



<u>Example</u>:

If y-axis = 71 inches and x-axis = 91 inches, then slope = 71/91.

1. Find the decimal equivalent for 71/91 can be found by dividing the denominator **into** the numerator:

$$91\overline{)71}$$

If you are using a calculator, type the numerator number first:

71
÷ symbol
91
= symbol

The decimal equivalent is 0.7802197802....

2. Round the number to the nearest ten-thousandths place, which will give us **0.7802**. (Note: The digit in the hundred-thousandths place is a "1", which is lower than 5, so the digit "2" in the ten-thousandths place stays the same.)

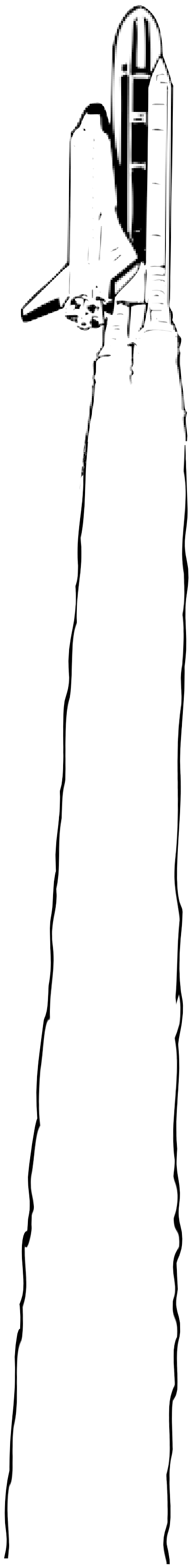
3. Estimate where the decimal might be found in the left column of the "Table for Determining Glide Slope". It would be found between 0.7536 (37 degrees) and 0.7813 (38 degrees).

4. Use subtraction to find the difference between **0.7802** and each of the other numbers. (Always subtract the bigger number minus the smaller number.)

0.7802	0.7813
- 0.7536	- **0.7802**
0.0266	0.0011

Since 0.0011 is smaller than 0.0266, **0.7802** is closer to 0.7813 than 0.7536.
Thus the glide slope that corresponds to 0.7813 is 38 degrees.

5. Write this glide slope value on the Landing Data Collection Sheet.



Practice finding the Glide Slope using the following fractions:

a) $\frac{62}{92}$

b) $\frac{55}{105}$

c) $\frac{73}{90}$

d) $\frac{63}{90}$

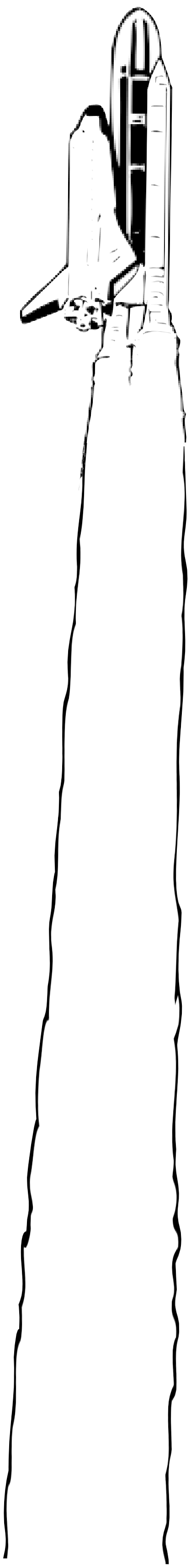
<u>How to Compute Flight Time</u>

1. When Mission Control Center gives the clearance signal, the copilot will release the glider.

2. At the same time, the mission specialist should start keeping track of the time.

3. The mission specialist must carefully watch the glider and “stop the timer” as soon as it comes to a complete stop on the runway.

4. The mission specialist should write the flight time (in seconds) on the Landing Data Collection Sheet.



How to Compute Average Speed

1. Write a fraction using the Total Distance to touchdown point as the numerator and the Flight Time as the denominator.

2. Average speed is written as a unit rate. To find the unit rate, divide the denominator **in to** the numerator. (If necessary, round the decimal to the nearest hundredths place. Label your answer with inches/second)

3. Ask the mission specialist to write this number on the Landing Data Collection Sheet.

Example:

If the Total Distance to touchdown point is 90 inches, and the Flight Time is 8 seconds, the fraction would be 90/8.

1. Find the average speed by dividing the denominator **in to** the numerator:

$$8 \overline{\big)\,90}$$

If you are using a calculator, type the numerator number first:

90
÷ symbol
8
= symbol

The average speed is 11.25 in/sec.

Practice finding the average speed using the following fractions:

a) $\frac{92}{10}$

b) $\frac{80}{6}$

c) $\frac{75}{8}$

d) $\frac{77}{9}$

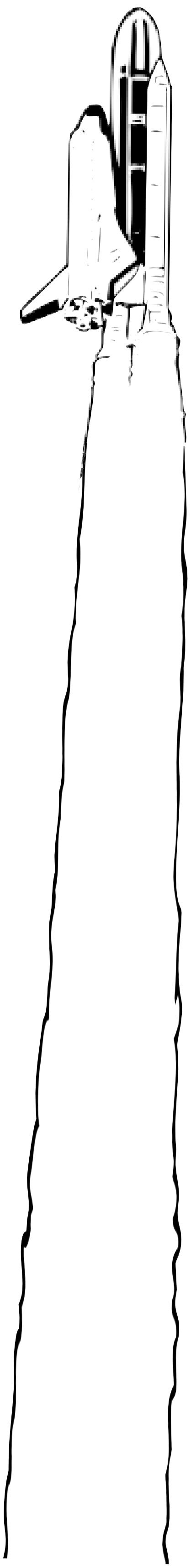
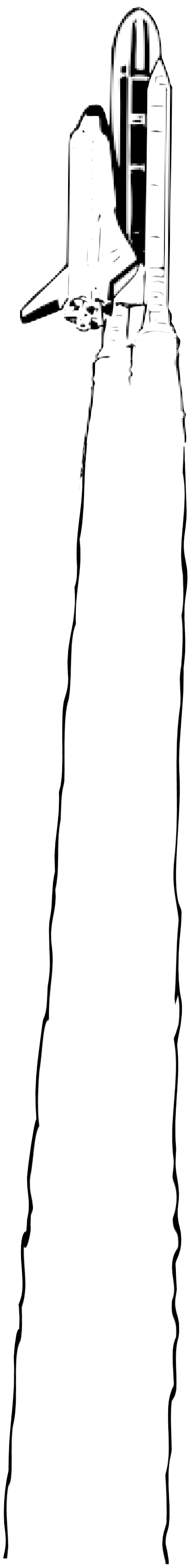


Table for Determining Glide Slope

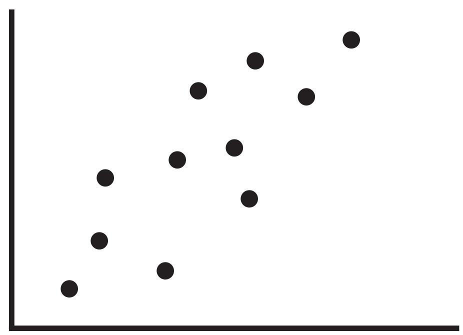
Decimal	Glide Slope	Decimal	Glide Slope
0.3839	21	1.0355	46
0.4040	22	1.0724	47
0.4245	23	1.1106	48
0.4452	24	1.1504	49
0.4663	25	1.1918	50
0.4877	26	1.2349	51
0.5095	27	1.2799	52
0.5317	28	1.3270	53
0.5543	29	1.3764	54
0.5774	30	1.4281	55
0.6009	31	1.4826	56
0.6249	32	1.5399	57
0.6494	33	1.6003	58
0.6745	34	1.6643	59
0.7002	35	1.7321	60
0.7265	36	1.8040	61
0.7536	37	1.8807	62
0.7813	38	1.9626	63
0.8098	39	2.0503	64
0.8391	40	2.1445	65
0.8693	41	2.2460	66
0.9004	42	2.3559	67
0.9325	43	2.4751	68
0.9657	44	2.6051	69
1.0000	45	2.7475	70



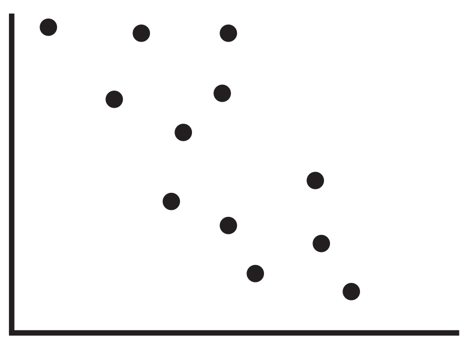
Purpose of a Scatter Plot

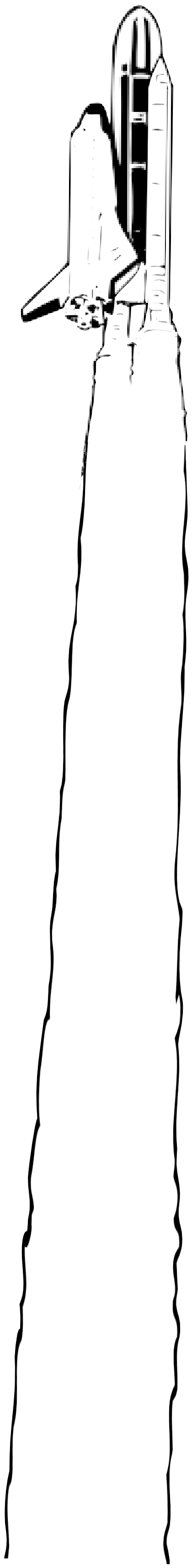
1. The purpose of a scatter plot is to show the type of relationship, or correlation, that exists between two sets of data.

   a. For instance, a positive correlation means that as the value of one set of data increases, the other data will also increase. An example of a "positive correlation" is the amount of rain and the size of puddles. Obviously, the more it rains, the larger the size of the puddles. In a scatter plot, "positive correlation" could look like this:

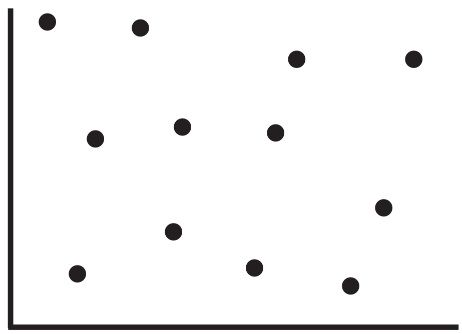


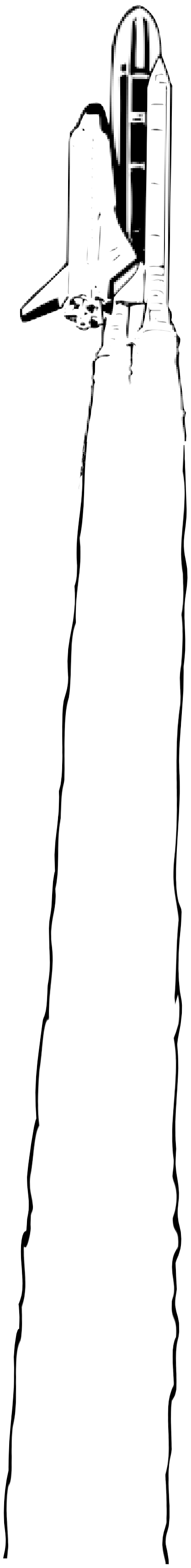
   b. There is a different type of relationship between the life of a watch and its battery. This specific example shows a "negative correlation" because the more the watch is in use, the less energy is left in its battery. In a scatter plot, "negative correlation" could look like this:





c. Lastly, there may be two sets of data that has "no correlation". In this relationship, the value of one set of data has neither "positive" nor "negative" effect on the other set of data. Imagine yourself drinking a glass of water. Do you now feel like doing more or less homework? Your answer to this question at that time would have nothing to do with drinking more water. This is because there is "no correlation" between how much water you drink and how much homework you do. In a scatter plot, "no correlation" could look like this:





Drawing a Line of Best Fit

2. If the scatter plot shows that the relationship between two sets of data has a positive or negative correlation, another use for the scatter plot is to be able to make predictions using a "line of best fit" or "fitted line". The line of best fit allows you to make predictions because every point on the line is associated with a glide slope value and average speed value. Thus, any value I choose for glide slope will have a corresponding average speed value, which can be found by locating the point on the line of best fit.

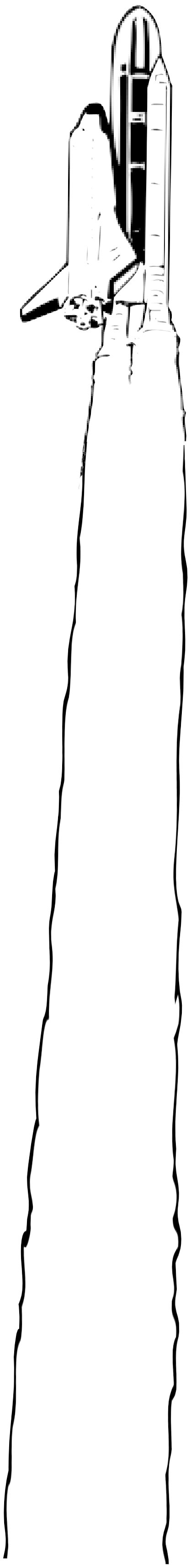
Here are the steps for drawing the line of best fit:

a. Be sure a positive or negative correlation exists.
b. Using a ruler, draw a line of best fit. You must use a ruler!

The line of best fit is an approximation. There isn't just one correct answer for drawing the line. Not everyone's line of best fit will be exactly the same. To draw a more accurate line, imagine the points are cities on a map and you want to be able to drive as close as you can to each city on **one, straight** road. Using a ruler, draw one, straight road that would take you as close as possible to every city. It is okay if your line goes through a city, and it is also okay if your line doesn't touch any of the cities. The goal is not to go through all the cities, so do not connect the dots. The goal is to get close to **all** the cities, using one, straight road.

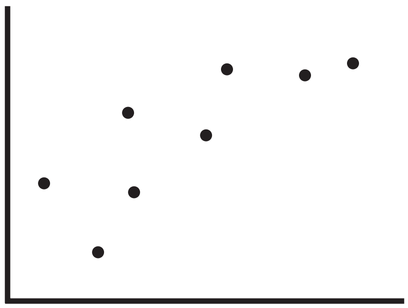
One technique you can use to draw the line is to hold the ruler on it's side and pretend it is the road you want to draw. Place it somewhere in the cities and look on either side of the road to make sure that it comes as close to all the cities as possible. You can move the road, simply by moving the ruler. Once you've found the perfect spot for your road, carefully mark the top and bottom of the ruler with a dot and draw your line.

c. Draw the line so that it goes as far left and as far right as possible without drawing the line through the axes and without drawing the line past the axes lines.

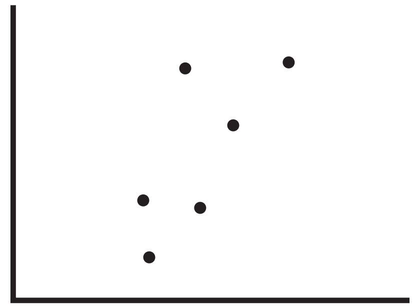


d. Practice drawing a line of best fit in each of the scatter plots below:

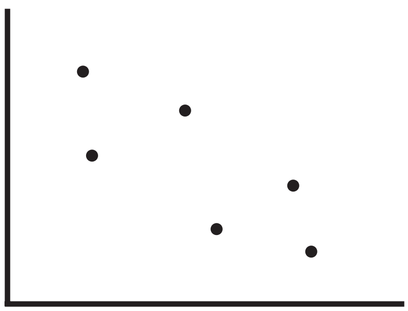
Practice Exercise #1:



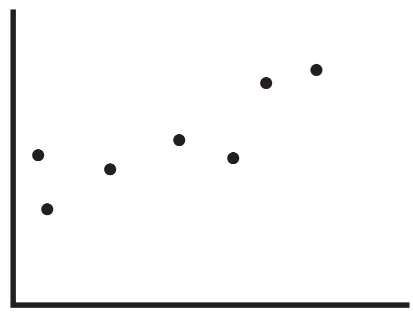
Practice Exercise #2:



Practice Exercise #3:



Practice Exercise #4:



<u>Using the Line of Best Fit for Making Predictions</u>

3. Here are the steps for using the line of best fit for making predictions

    a. Choose a glide slope value from the x-axis.

    b. Hold your ruler vertically (parallel to the sides of your paper) to find the point on the line of best fit that is exactly above the glide slope value you selected from the x-axis. Mark that point.

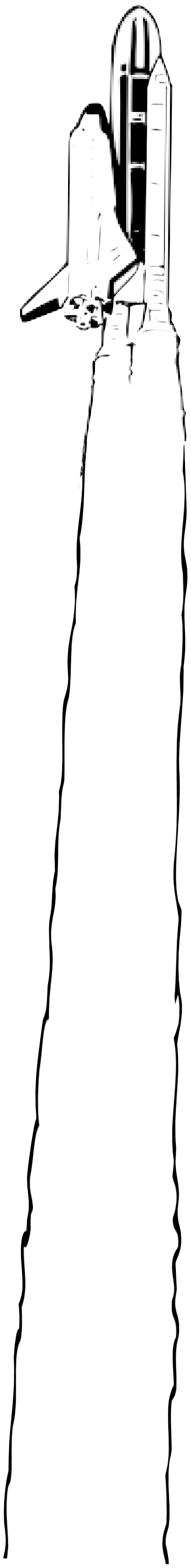
    c. Hold your ruler horizontally (parallel to the bottom of your paper) and line it up with the mark you made on the line of best fit to find the point on the y-axis. Mark that point.

    d. Determine the value of the speed.

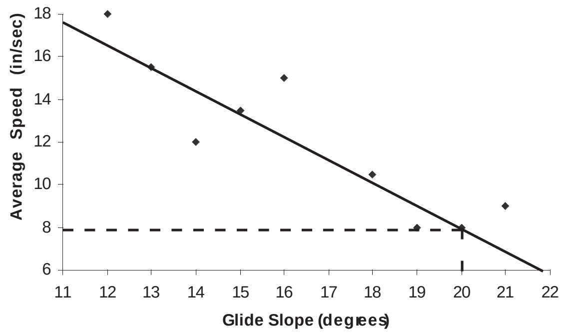
    e. This value is an educated approximation of the average speed of the glider according to the glide slope.

    f. The same procedure can be done in reverse to find the approximation of the glide slope if you choose an average speed value from the y-axis.

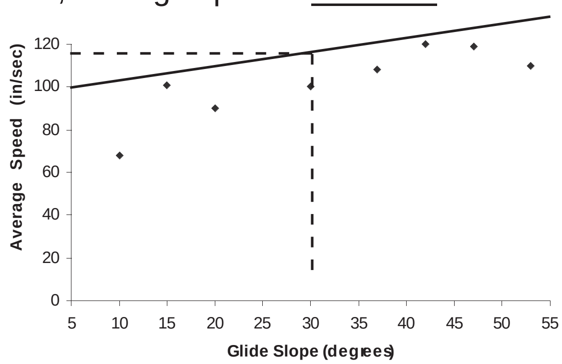
    g. Practice making predictions by using the scatter plots on the following page:



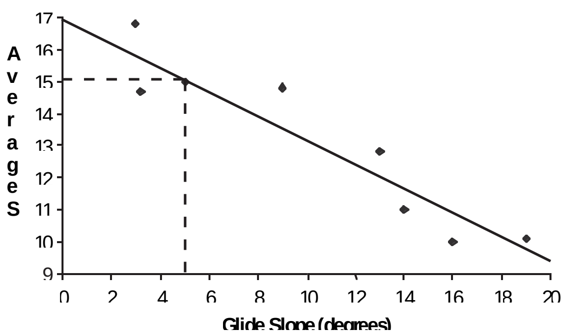
Practice Exercise #1:
If glide slope value = 20 degrees
Then, average speed = ________ in/sec



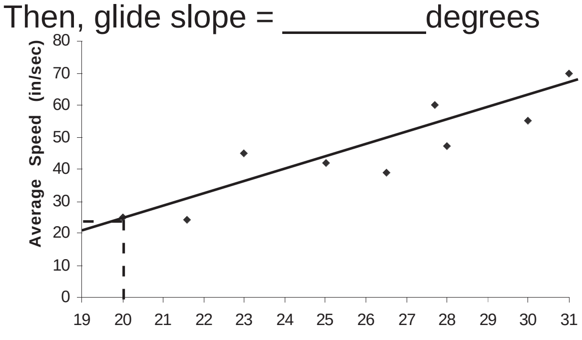
Practice Exercise #2:
If glide slope value = 30 degrees
Then, average speed= _______ in/sec

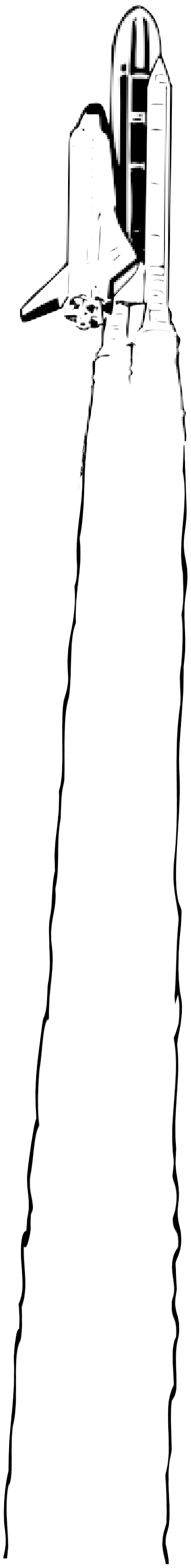


Practice Exercise #3:
If average speed = 15 in/sec
Then, glide slope = ________ degrees



Practice Exercise #4:
If average speed = 25 in/sec
Then, glide slope = ________degrees





How to Create a Scatter Plot

To create a scatter plot for this activity:

1. Draw a graph with an x-axis and a y-axis like the one on the following page.

2. Label the graph with a title such as “Relationship between Glide Slope and Average Speed.”

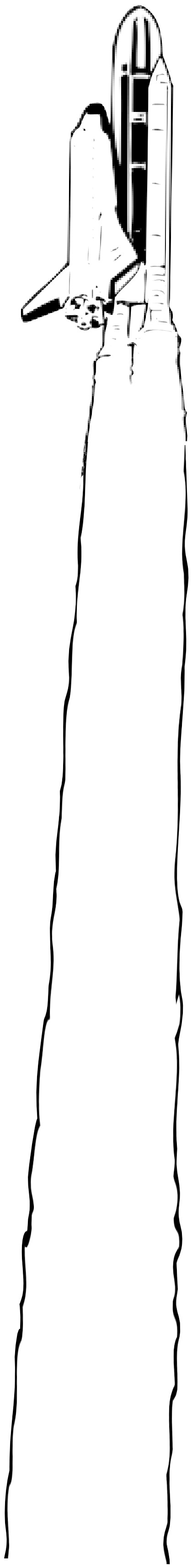
3. Label the x-axis as Glide Slope (degrees) and label the y-axis as Average Speed (inches/second).

4. Determine marks for intervals that will effectively use the amount of space on your paper.
   a. A good distance to use between “marks” is 1 cm.

   b. Each “mark” has an interval that is determined by the highest and lowest values of both the x-axis and y-axis (in this case Glide Slope and Average Speed).

   c. Intervals that are commonly used include: 1s, 2s, 5s, 10s, 20s, 25s, 50s, 100s.

   d. An 8 1/2" x 11" paper can easily fit 15- 1cm “marks” horizontally, and 20- 1cm “marks” vertically.

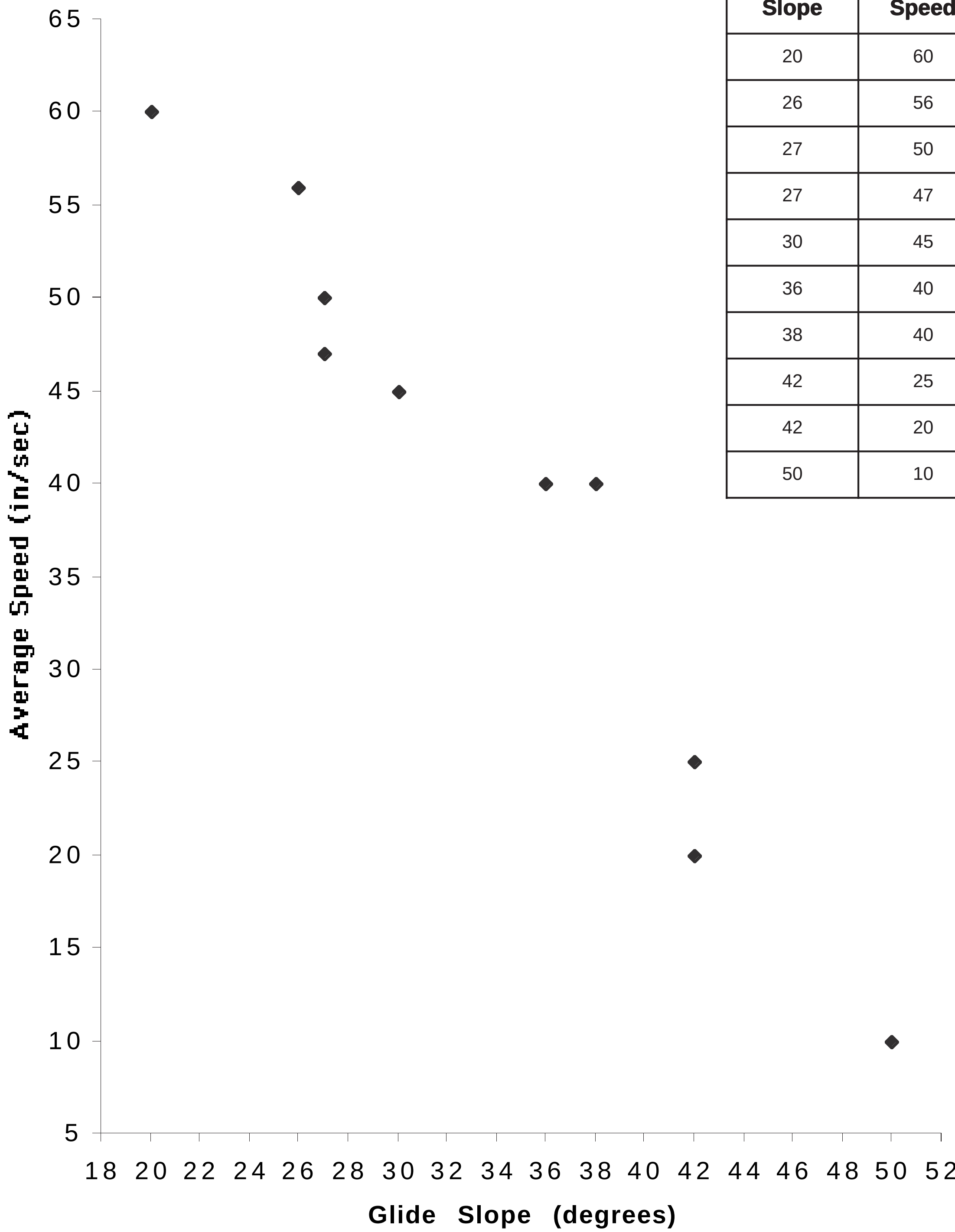


Example:
If the values on the x-axis range from 20 to 50, then intervals of 2s would require 15 intervals. This means all the values from 20 to 50 can fit by counting by 2s, and by making “marks” 1cm apart.

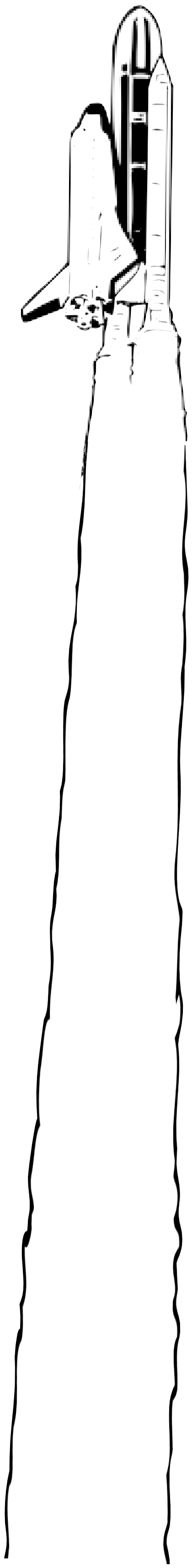
If the values on the y-axis range from 10 to 60, then intervals of 2s would require 25-1cm intervals. Another option would be to use intervals of 5s which would require only 10 intervals. In this case, to maximize the amount of space on the paper, 2 cm intervals could be used instead of 1cm intervals.

<u>Relationship between Glide Slope and Average Speed</u>

Glide Slope	Average Speed
20	60
26	56
27	50
27	47
30	45
36	40
38	40
42	25
42	20
50	10



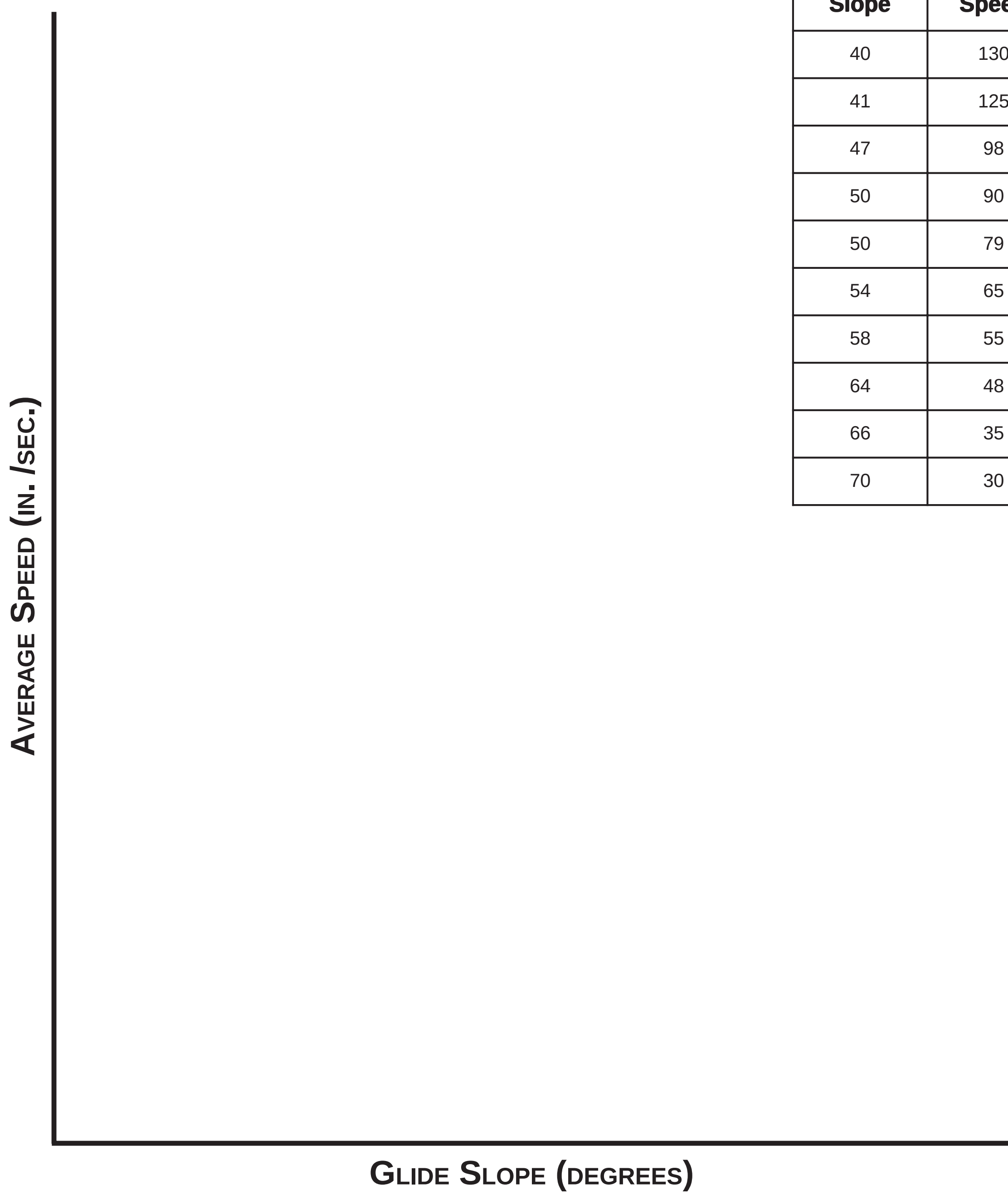
Practice:
Using a ruler, “mark” off both axes to include the entire range of values from highest to lowest for both the Glide Slope and the Average Speed.



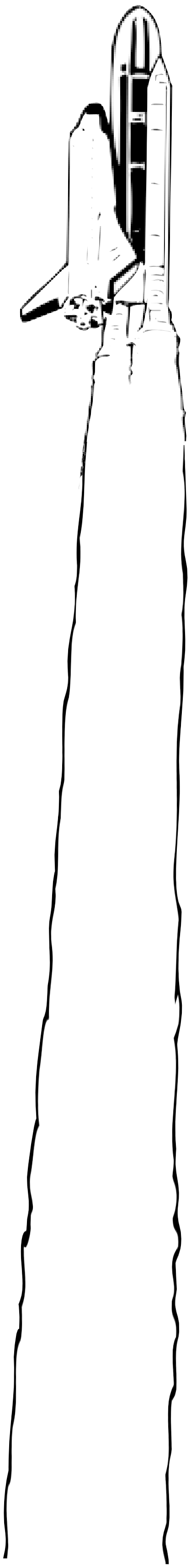
Plot each point using both the Glide Slope value (x-axis) and the Average Speed value (y-axis). In other words, you need both the Glide Slope and Average Speed numbers to make just one point. You should have 10 points all together.

1.
Relationship between Glide Slope and Average Speed

Glide Slope	Average Speed
40	130
41	125
47	98
50	90
50	79
54	65
58	55
64	48
66	35
70	30



2. Do you notice any type of correlation in the points?
   If yes, what type of correlation do you see? ________

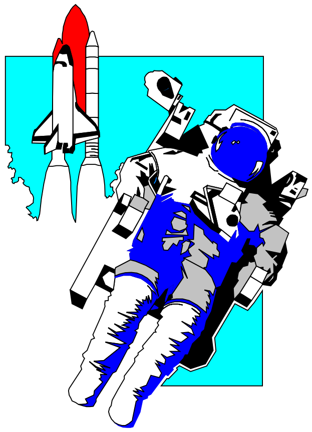


3. Using a ruler, draw a line of best fit.
   Using the line of best fit, what would be the average speed for a glide slope of:

Glide Slope	Average Speed
44	________________
52	________________
60	________________

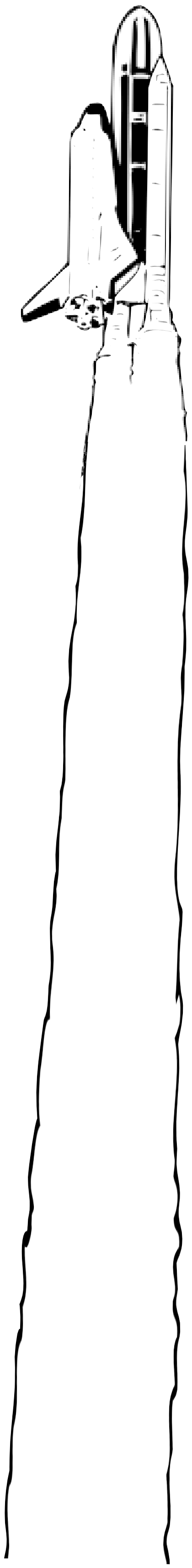
4. Using the line of best fit, what would be the glide slope for an average speed of:

Average Speed	Glide Slope
40	________________
60	________________
110	________________



Student Mathematics Activity: Carry That Weight

Student Mathematics Activity: Carry That Weight



Student Background

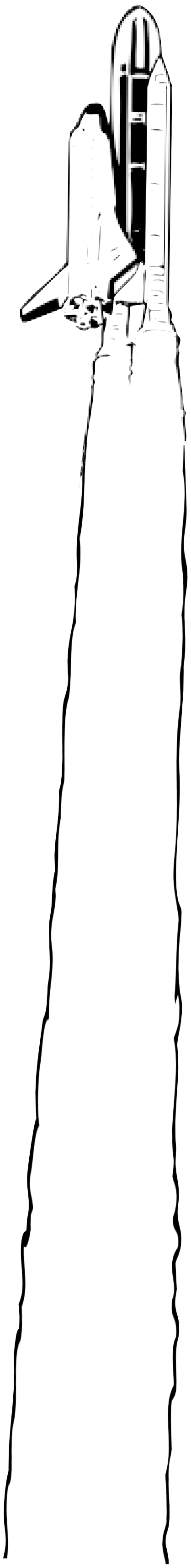
The orbiter must travel through more than 60 miles of the Earth's atmosphere to reach space. The total weight of the orbiter, its crew, payload, fuel tanks, rocket fuel and other miscellaneous items must not be greater than the amount of thrust it would take to propel it to an orbit just outside of the thermosphere.

Using mathematical calculations, rocket researchers have been able to determine just how much thrust is needed to launch a certain amount of weight. With a fully loaded orbiter and fuel tanks, it takes over 5 million pounds of thrust to launch the orbiter into space. To determine this amount of thrust NASA must consider the weight of every item being taken on each mission. The approximate weight of each item is listed in the chart below.

Space Shuttle Mission Weight Chart

Item Description	Weight (in kilograms)
Orbiter (empty)	43,092
Payload (standard maximum weight)	24,948
External Tank (full)	750,980
Solid Rocket Booster (each)	589,670
(x 2 =)	1,179,340
Other: • Crew members (3-10) • Additional fuel for use during mission • Liquids & gases for electrical production & environmental conditioning	14,850

Student Mathematics Activity: Carry That Weight (continued)



Directions: As Director of the next space shuttle mission to be commanded by Eileen Collins, you will be in charge of making sure the orbiter's maximum weight does not exceed 102,600 kg. Follow the steps below and complete the chart on the next page.

1. Choose 4 of your classmates to join you and Commander Collins on the next mission. Record each classmate's name and each classmate's weight in kilograms.

Crew Members Weight

Crew Member		Weight In Kilograms
Commander Collins	=	60
My Name: _______________	=	
Classmate:_______________	=	
Classmate:_______________	=	
Classmate:_______________	=	
Classmate:_______________	=	
Total Crew Weight	=	

2. Choose what will be brought on this mission from the payloads listed below by checking each item you will bring. Then total their combined weight. Make sure you do not exceed (go over) the total mission weight. Record the total payload weight here: __________________________.

Space Habipod = 18,000 kg

Curie Deep Space Observatory = 21,150 kg

Weather Satellite = 17,100 kg

Amateur Radio Station Experiment = 1,800 kg

Spectrometer Tests = 1,125 kg

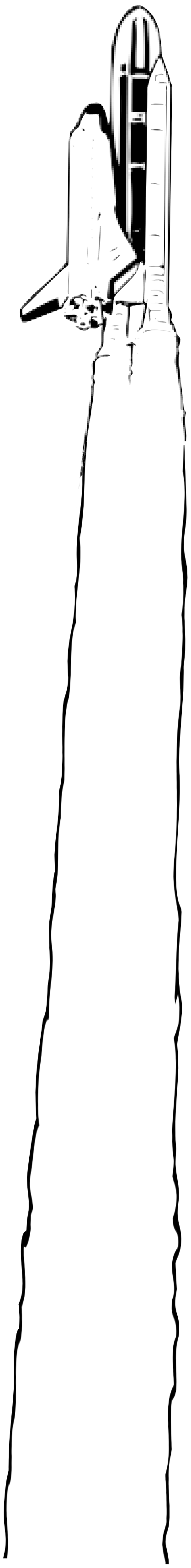
Microgravity Lab Experiment Kit = 2,700 kg

Atmospheric Lab = 4,590 kg

U-V Telescope Experiment = 3,555 kg

Global Positioning Systems Check = 900 kg

Student Mathematics Activity: Carry That Weight (continued)

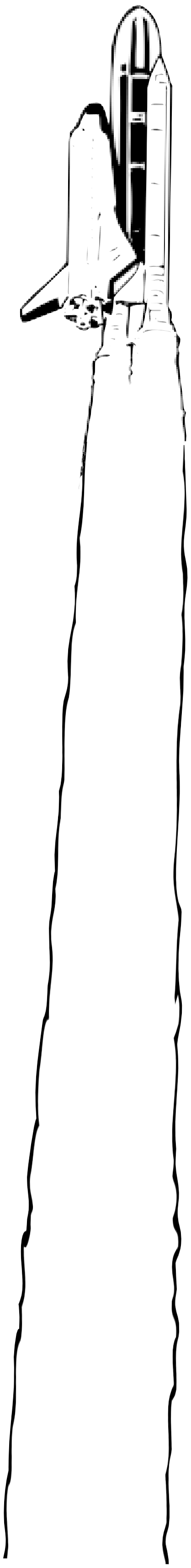


3. Complete the chart on this page by using information from the Space Shuttle Mission Weight Chart and the Crew Members Weight from the previous pages.

Your Mission Weight Chart

Item Description	Weight (in kilograms)
Orbiter (empty)	
Payload	
External Tank (full)	
Solid Rocket Booster (each)	589,670
x 2 =	
Other:	
• Crew members (6)	
• Additional fuel for use during mission • Liquid & gases for electrical production & environmental conditioning (together)	~14,490
Total Mission Weight (not to exceed 2,013,210)	

Student Mathematics Activity: Carry That Weight - Key

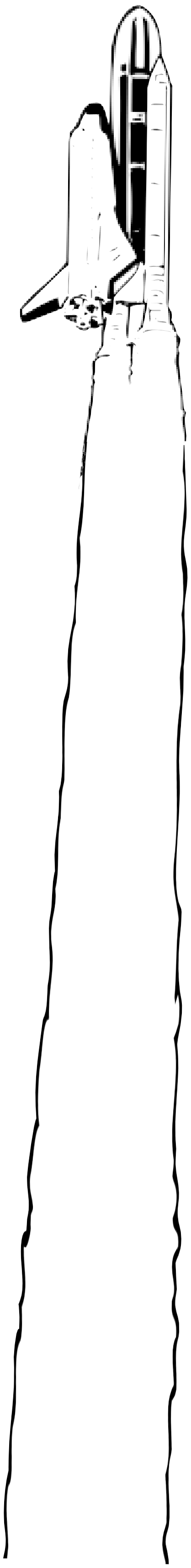


3. Complete the chart on this page by using information from the Space Shuttle Mission Weight Chart and the Crew Members Weight from the previous pages.

Your Mission Weight Chart

Item Description	Weight (in kilograms)
Orbiter (empty)	43,092
Payload	~ 24,948
External Tank (full)	750,980
Solid Rocket Booster (each)	589,670
x 2 =	1,179,340
Other:	
• Crew members (6)	~ 360
• Additional fuel for use during mission • Liquid & gases for electrical production & environmental conditioning (together)	~ 14,490
Total Mission Weight (not to exceed 2,013,210)	*answers will vary*

Student Mathematics Activity: Carry That Weight
Let's Convert

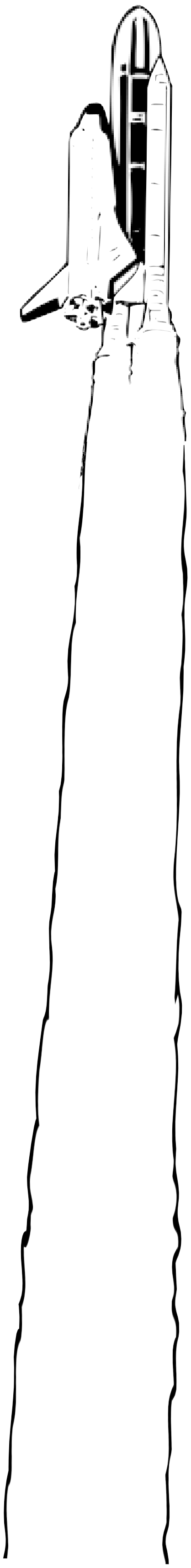


Directions: Use the given measurements to convert the weights into kilograms, pounds and tons. In the final column, name an object (or a number of them) that would weigh the same amount.

Mission Weight Chart Conversion

Item Description	**Weight**			
	kilograms	pounds	tons	familiar object
Orbiter (empty)	43,092			
Payload (standard maximum weight)			27.44	
External Tank (full)		1,652,156		
Solid Rocket Booster (each)	589,670			
(x 2 =)				
Other: • Crew members • Additional fuel for use during mission • Liquids & gases for electrical production & environmental conditioning		33,000		
Total Lift-Off Weight			2214.5	

Student Mathematics Activity: Carry That Weight
Let's Convert - Key

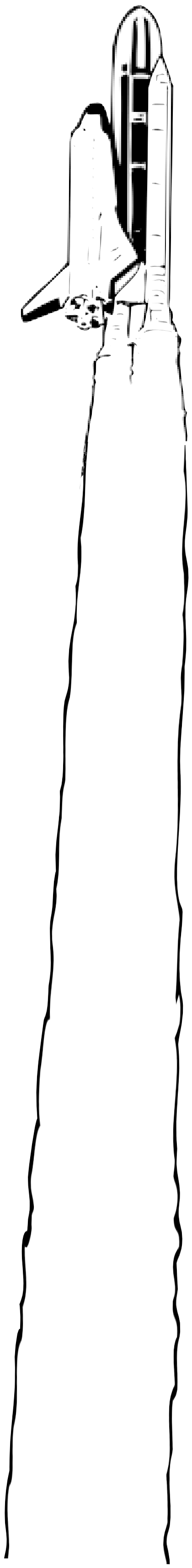


Directions: Use the given measurements to convert the weights into kilograms, pounds and tons. In the final column, name an object (or a number of them) that would weigh the same amount. *Depending upon the conversion method used, answers will vary. Two answers for tons are given for ease in checking answers.*

Mission Weight Chart Conversion

Item Description	**Weight**			
	kilograms	pounds	tons	familiar object
Orbiter (empty)	43,092	94,802.4	47.5 47.4	1 big rig truck
Payload (standard maximum weight)	24,948	54,885.6	27.44	5 elephants
External Tank (full)	750,980	1,652,156	827.98 826.08	16 big rig trucks
Solid Rocket Booster (each)	589,670	1,297,274	650.13 648.64	13 big rig trucks
(x 2 =)	1,179,340	2,594,548	1,300.26 1,297.27	26 big rig trucks
Other: • Crew members • Additional fuel for use during mission • Liquids & gases for electrical production & environmental conditioning	14,850	33,000	16.37 16.5	3 elephants
Total Lift-Off Weight	2,013,210	4,429,062	2,219.6 2,214.5	44 big rig trucks

Student Mathematics Activity: Carry That Weight
Teacher Conversion Hints



To convert from kilograms to pounds

(kg to lbs.) **kg x 2.2 = lbs.**

To convert from pounds to kilograms

(lbs. to kg) **lbs. x .45 = kg**

To convert from pounds to tons

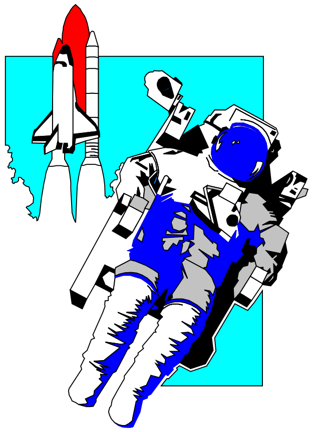
(lbs. to tons) **lbs. / 2,000 = tons**

To convert from tons to pounds

(tons to lbs.) **tons x 2,000 = lbs.**

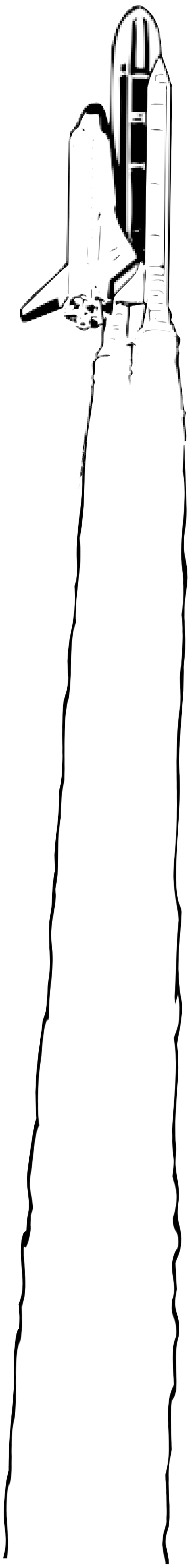
To convert from kilograms to tons

(kg to tons) **kg / 907 (907.2) = tons**



Student Science Activity: Everything's Under Control

Student Science Activity: Everything's Under Control



Overview

This activity is designed to allow students to explore the basic control surfaces of the orbiter and the motions they affect by having the students perform a hands-on experiment that will demonstrate the orbiter's movement during flight. This 2 – 3 session activity is designed for students in grades 4 – 8. It is primarily a hands-on experiment complemented by a student informational reading, comprehension worksheet, experiment guidesheet and a series of photos displaying the experiment's set-up. Students will construct pre-fabricated space shuttle orbiters with movable control surfaces that will be used to demonstrate the motions of roll, pitch and yaw. The students will manipulate each control surface (rudder, elevons: elevators/ailerons) on the glider and determine which motion each affects. They will observe, and record their findings. From this data they will determine that the rudder affects yaw, the outer elevons (acting as ailerons) affect roll, and the inside elevons (acting as elevators) affect pitch. They will also demonstrate that the outer elevons (ailerons) act in opposition (one in the up position and the other in the down position). While the inner elevons (elevators) act in tandem (both in the up position or both in the down position).

Grade Levels

Grades 4 – 8

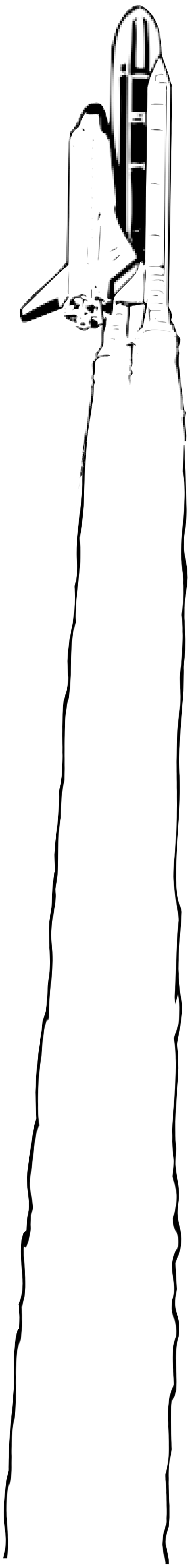
Time Frame

2 – 3 class sessions of 45 – 60 minutes

Key Questions

1. What are the motions of the orbiter?
2. How is the orbiter controlled?
3. What control surfaces are used on the orbiter?
4. What motions are affected by each control surface?

Student Science Activity: Everything's Under Control (continued)



Materials

1. Control Surface Experiment Data Sheets #1, #2, #3
2. Student Informational Reading: Orbiter Control
3. Student Comprehension Worksheet: Orbiter Control
4. Pre-fabricated Space Shuttle Glider (recommended commercially-made glider with movable control surfaces: *White Wings Space Shuttle*™.

Getting Ready

1. Run multiple copies of student handouts:
2. Decide where the "fly zone" will be located.
3. Purchase pre-fabricated gliders (Recommended *White Wings Space Shuttle™)*

Teacher Background *See Student Informational Reading: Orbiter Control*

Vocabulary

1. **aileron**: Control surfaces on the trailing edge of each wing that affect the motion of roll.

2. **axis**: A straight line through the center of gravity around which an aircraft rotates.

3. **center of gravity**: A point on an airplane at which the entire weight of the airplane is considered concentrated so that if the airplane is supported at this point the airplane would remain in equilibrium (or balance).

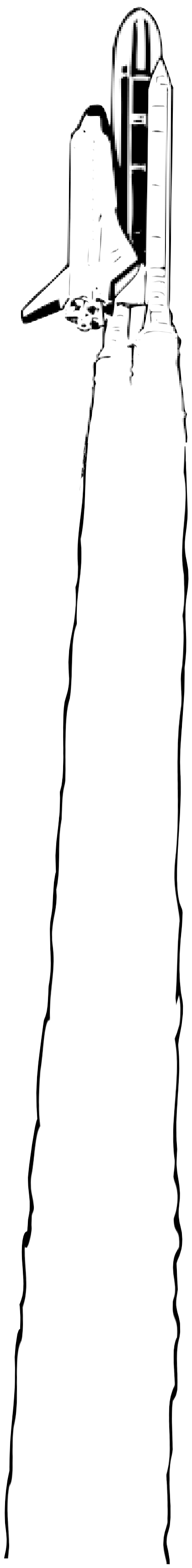
4. **drag**: The force that resists the motion of the aircraft through the air.

5. **elevator**: Control surfaces on the horizontal part of the tail section (horizontal stabilizer) that affects the motion of pitch.

6. **elevon**: Control surfaces located on the trailing edge of a delta wing airplane that control the motion of pitch and roll.

7. **force**: A push or pull in a certain direction that can be measured.

Student Science Activity: Everything's Under Control (continued)



Vocabulary - Continued

8. **lift**: Upward force produced by air passing over and under the wing of an airplane.

9. **lateral axis:** The axis extending through the center of gravity of an airplane and parallel to a line connecting the tips of the wings.

10. l**ongitudinal axis:** The axis extending through the center of the fuselage from the nose to the tail.

11. **pitch**: A rotational motion in which the aircraft turns around its lateral axis by raising or lowering the nose of the airplane.

12. **roll**: A rotational motion in which the aircraft turns around its longitudinal axis by raising one wing higher as the other wing dips lower.

13. **rudder**: A control surface on the trailing edge of the vertical part of the tail section (vertical stabilizer) that affects the motion of yaw.

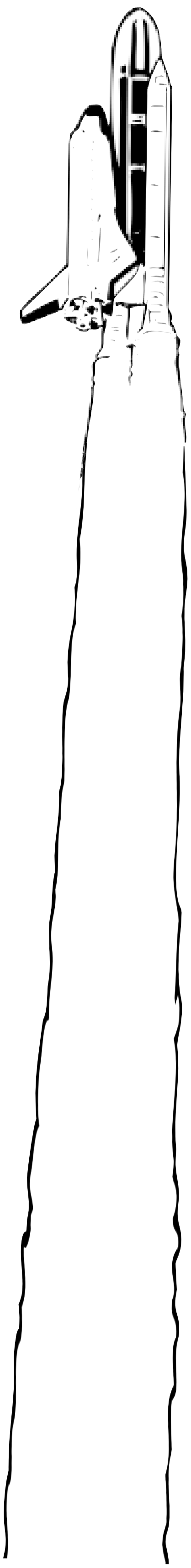
14. **thrust**: A force created by the engines that pushes an aircraft through the air.

15. **weight**: A force of gravity acting on an object.

16. **vertical axis**: The axis extending straight up and down through the center of gravity of an aircraft.

17. **yaw**: A rotational motion in which the aircraft turns around its vertical axis by moving the nose of the aircraft to the pilot's left or right.

Student Science Activity: Everything's Under Control (continued)



Prerequisite Knowledge

1. Familiarity with the motions of an airplane: roll, pitch, yaw.
2. Familiarity with the 3 axes: lateral, longitudinal and vertical.

Skills

1. Reading for meaning
2. Observation of flight
3. Data collection

Concepts

1. Rudder affects the motion of yaw (horizontal axis).

2. Elevon is a control surface located along the trailing edge of a delta wing and is actually a combination of an <u>elev</u>ator and an ailer<u>on</u>.

3. The elevator (inner elevon on the orbiter's delta wings) affects the motion of pitch (vertical axis).

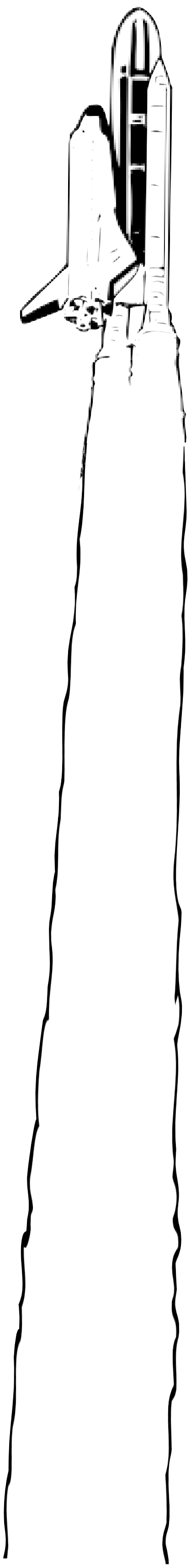
4. The aileron (outer elevon on the orbiter's delta wings) affects the motion of roll (lateral axis).

5. Ailerons (outer elevons) work in opposition.

6. Elevators (inner elevons) work in tandem.

Processes

1. Use the scientific method to answer a question.
2. Perform research to gather additional information.
3. Making models.



Session 1

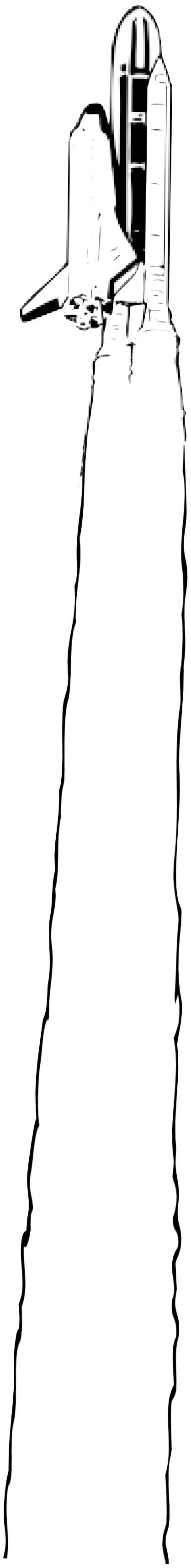
- Show videotape footage (or use the animation from the Female Frontiers Web site) of the space shuttle (orbiter) landing. Discuss with the students the path the orbiter flies during descent along with an explanation as to why it flies such a descent route. Point out the different motions the orbiter uses as it descends to land. (See "Student Informational Reading: Orbiter Control")

- Using a model of the orbiter demonstrate and review the 3 motions of an airplane (glider): roll, pitch, yaw. (See overhead transparencies of "Axes and Orbiter Motions".) At this point, the teacher can choose to introduce control surfaces providing for or reviewing with the students what they are, what motions they affect, and how they work OR merely point out on the glider model that there appears to be some hinged surfaces on the model. If taking the latter approach, then query the students as for what each of the hinged surfaces might be used.
- Pose and discuss the questions below:
  1. What are the 3 basic motions of an airplane?
  2. Can you describe each motion or demonstrate how each motion moves?
  3. How does the commander and pilot of the orbiter control these motions?
  4. Where on the orbiter are these control surfaces located?
  5. What motion does each control surface control?
  6. How can we find out answers to some of these questions?

- Lead the students towards defining an experiment which would use the glider model to test or demonstrate the control surfaces of the orbiter. The experiment should include manipulating the hinged surfaces, flying the glider, observing its flight motion and recording their observations. Have students in small groups or pairs develop a set of procedures for such an experiment (or simply review the procedure and template already provided).

- Have students record their set of procedures on chart paper, post and present their steps to the class. From the different sets of procedures have the class develop one definitive procedure list detailing how each team will perform the experiment. Record the final set of procedures on chart paper and post.

Student Science Activity: Everything's Under Control (continued)



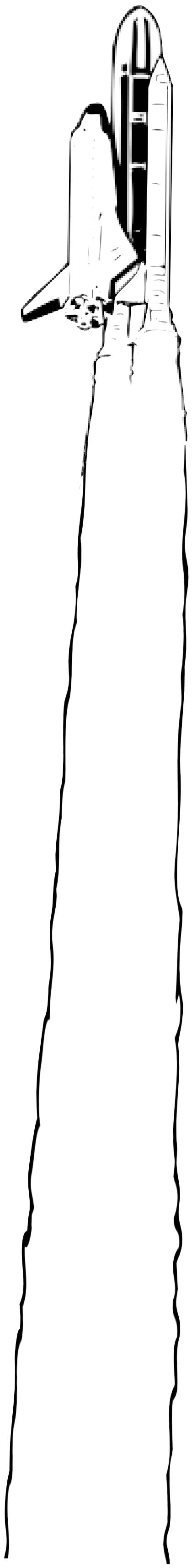
Session 2

- Review the motions of roll, pitch and yaw using the overhead transparencies, animation found on the Web site and orbiter glider.
- Review the posted set of procedures for the class to follow for the experiment.
- Distribute "Experiment Data Sheets #1, #2, #3" and space shuttle gliders.
- Have students assemble space shuttle gliders.
- Review safety considerations.
- Allow 30 minutes for experiment.
- Have teams or partners meet in small groups of 4 – 6 students and consolidate findings using the "Experiment Conclusion Report". Have them then transfer the information from that sheet onto a large sheet of chart or butcher paper for posting.
- Collect and post for the next session's discussion.

Session 3

- Review and discuss each group's "Experiment Conclusion Report" that was posted from previous assignment.
- If any disagreement results from the posted information. Clarify by having you or a student re-test the glider with the disputed control surface/motion in each position, and flying it in front of the class.
- Distribute the "Descent Control" assessment and have students using the posted information, answer each question.
- Collect the "Descent Control" for evaluation.
- Review the answer key for "Descent Control" for wrap-up.
- Have students complete their "Self-Evaluation Check-Up" regarding their work on the activity.

Student Science Activity: Everything's Under Control (continued)



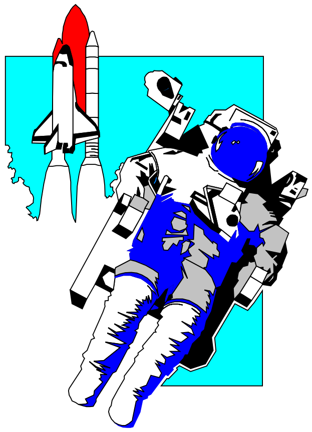
Teacher Section

- Overhead Transparencies
  - Axes and Orbiter Motion
  - Orbiter Control Surfaces with Descriptions
  - Orbiter Control Surfaces Experiment Procedure List
  - Orbiter Control Surfaces Experiment
  - Experiment Procedure: Experiment #1
  - Experiment Procedure: Experiment #2
  - Experiment Procedure: Experiment #3

- Answer Keys
  - Control Surface Experiment Data Sheet #1 - Key
  - Control Surface Experiment Data Sheet #2 - Key
  - Control Surface Experiment Data Sheet #3 - Key
  - Experiment Conclusion Report - Key
  - Student Worksheet: Orbiter Control - Key
  - Student Worksheet: Descent Control - Key

Student Handouts

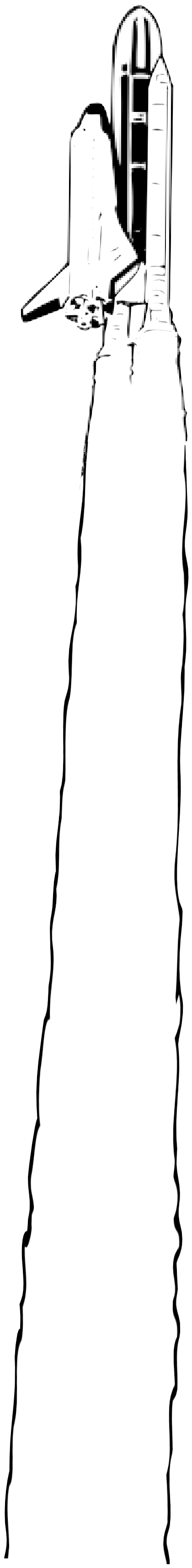
- Control Surface Experiment Data Sheet #1
- Control Surface Experiment Data Sheet #2
- Control Surface Experiment Data Sheet #3
- Experiment Conclusion Report
- Student Informational Reading: Orbiter Control
- Student Worksheet: Orbiter Control
- Student Worksheet: Descent Control
- Self-Evaluation Check-Up

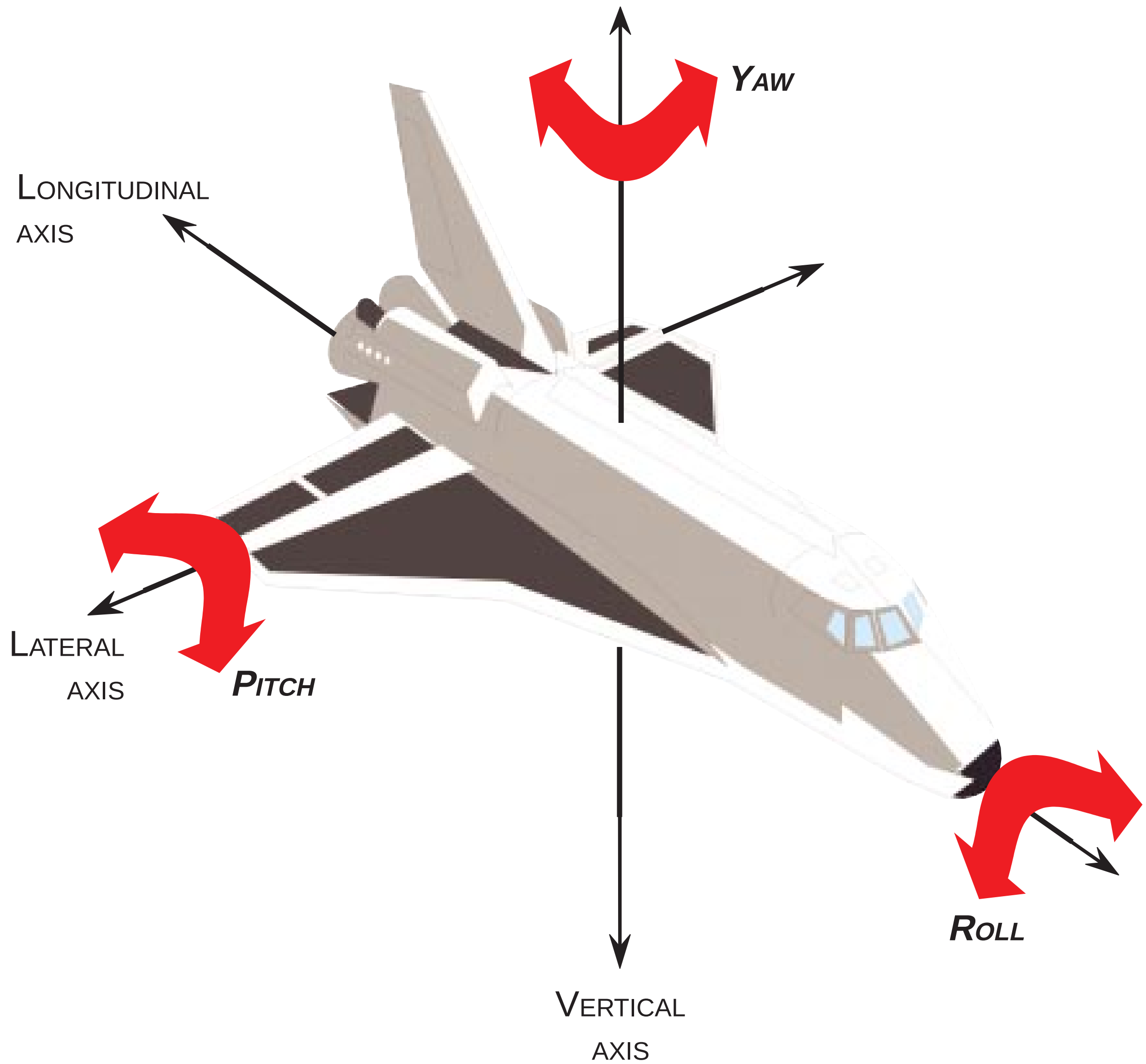


Student Science Activity: Everything's Under Control

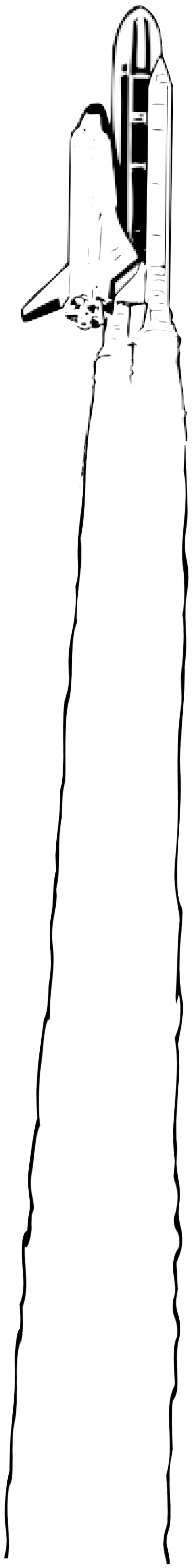
Teacher Section

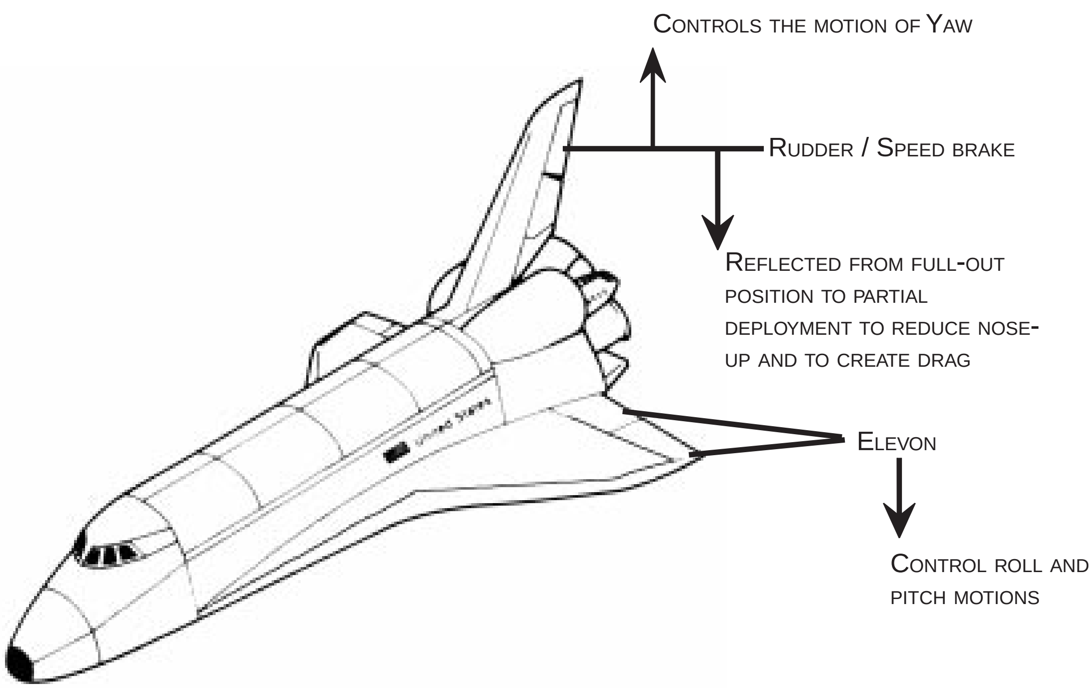
Axes and Orbiter Motion

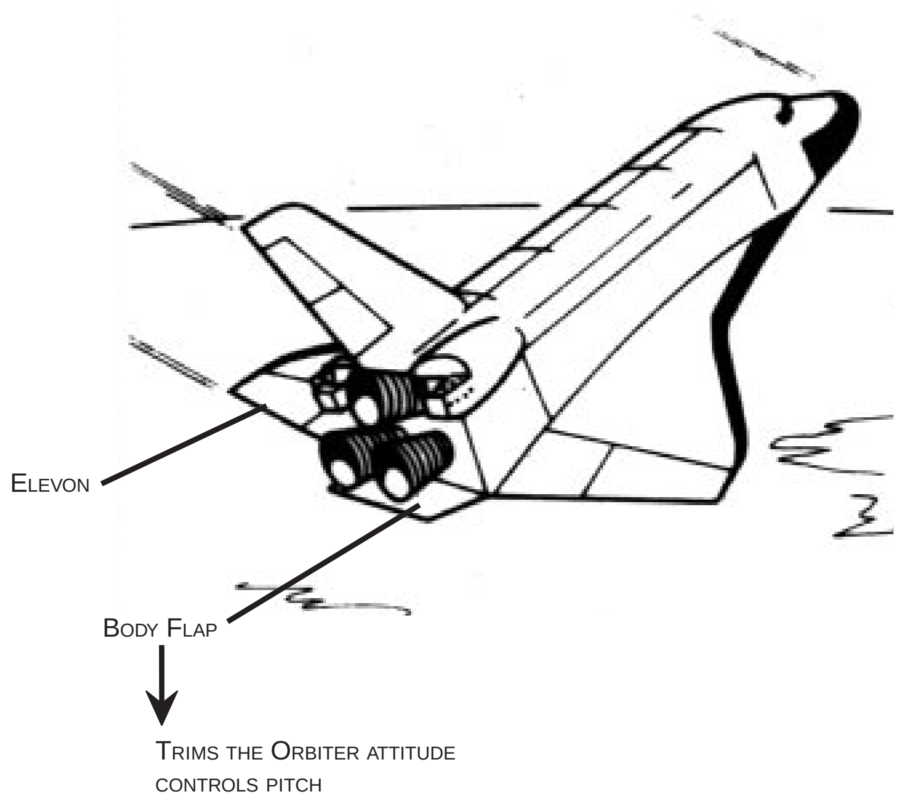




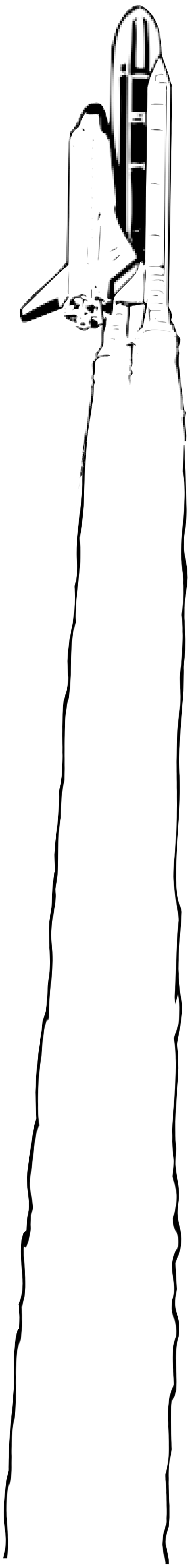
Orbiter Control Surfaces With Descriptions







Orbiter Control Surfaces Experiment Procedure List



Experiment #1

1. Bend left inner elevon up and right inner elevon down.
2. Launch glider.
3. Observe flight.
4. Record observations.
5. Bend left inner elevon down and right inner elevon up.
6. Repeat steps #2 - #4.
7. Bend left inner elevon up and right inner elevon up.
8. Repeat steps #2 - #4.
9. Bend left inner elevon down and right inner elevon down.
10. Repeat steps #2 - #4.

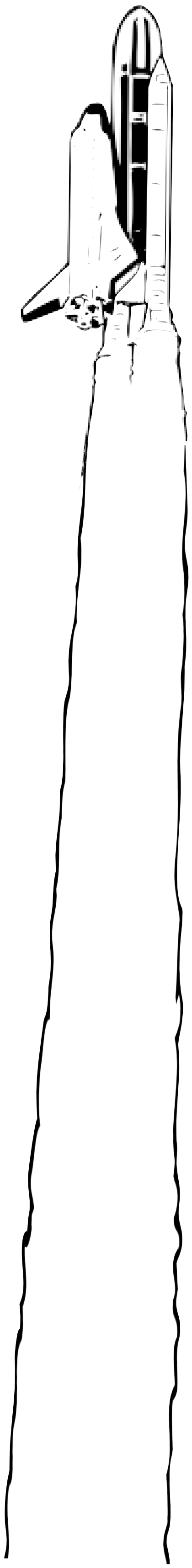
Experiment #2

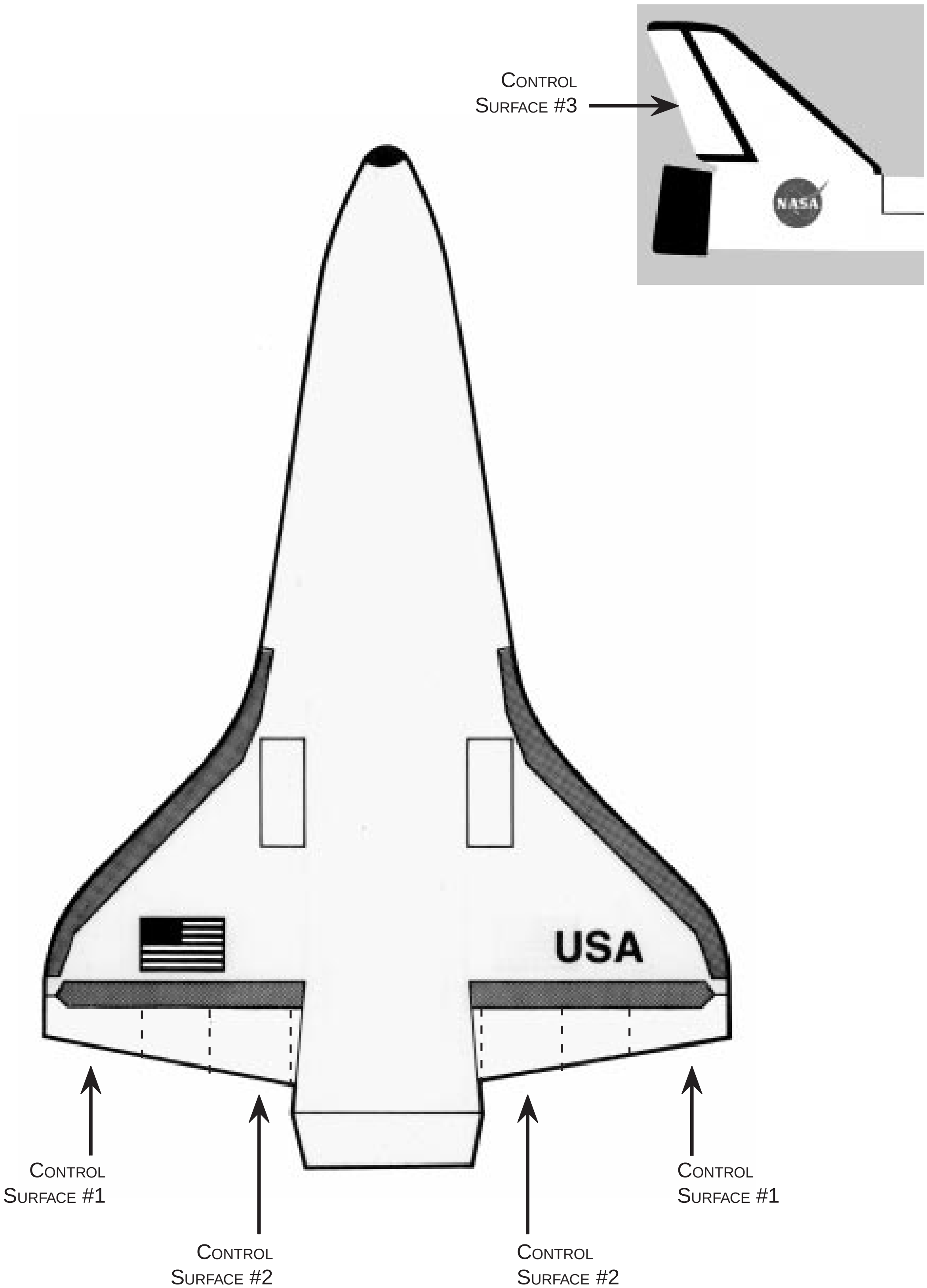
1. Bend left outer elevon up and right outer elevon down.
2. Launch glider.
3. Observe flight.
4. Record observations.
5. Bend left outer elevon down and right outer elevon up.
6. Repeat steps #2 - #4.
7. Bend left outer elevon up and right outer elevon up.
8. Repeat steps #2 - #4.
9. Bend left outer elevon down and right outer elevon down.
10. Repeat steps #2 - #4.

Experiment #3

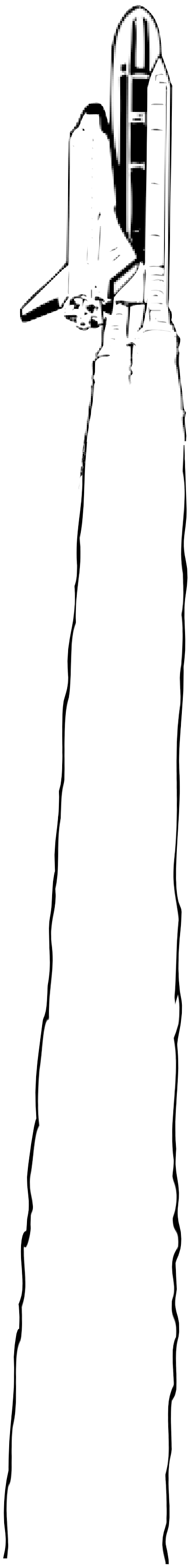
1. Bend rudder right.
2. Launch glider.
3. Observe flight.
4. Record observations.
5. Bend rudder left.
6. Repeat steps #2 - #4.

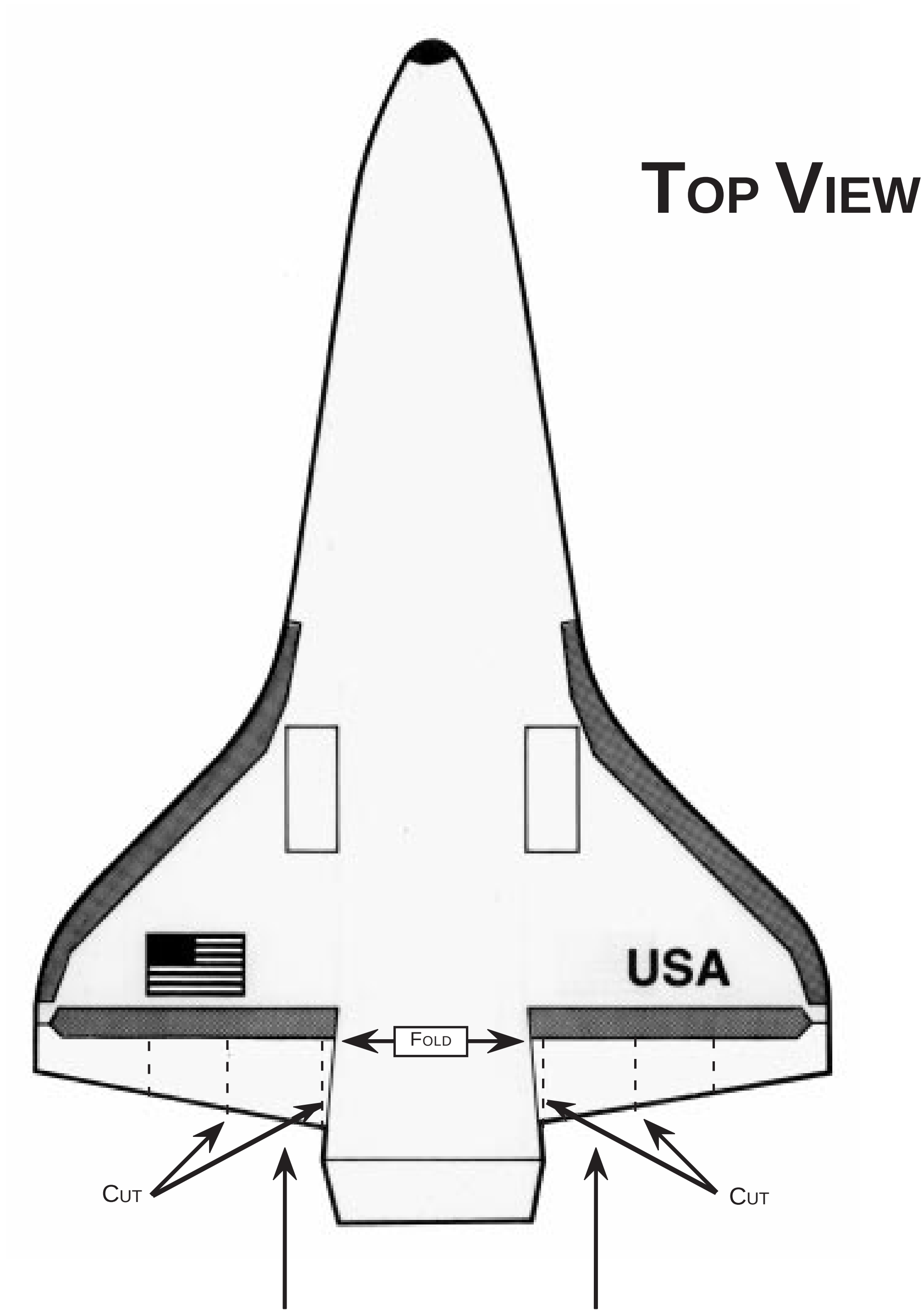
Orbiter Control Surfaces Experiment





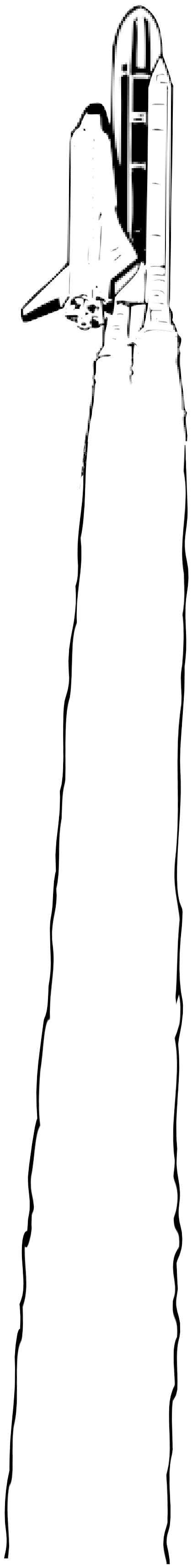
Experiment Procedure Experiment #1

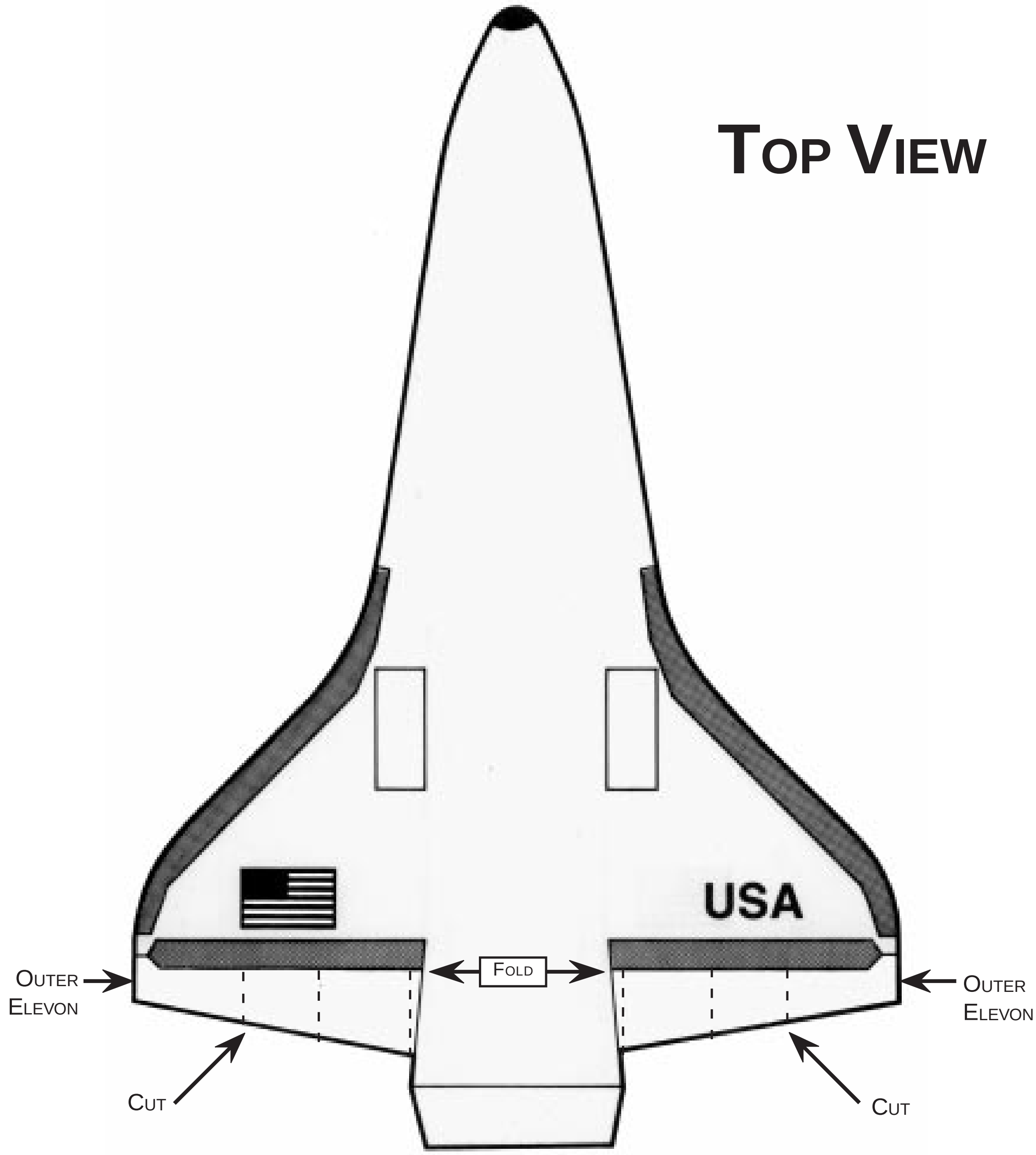




Inner Elevon	Inner Elevon
1. Left-Up then	1. Right-Up then
2. Left -Down then	2. Right -Down then
3. Left-Up then	3. Right-Down then
4. Left-Down	4. Right-Up

Experiment Procedure Experiment #2

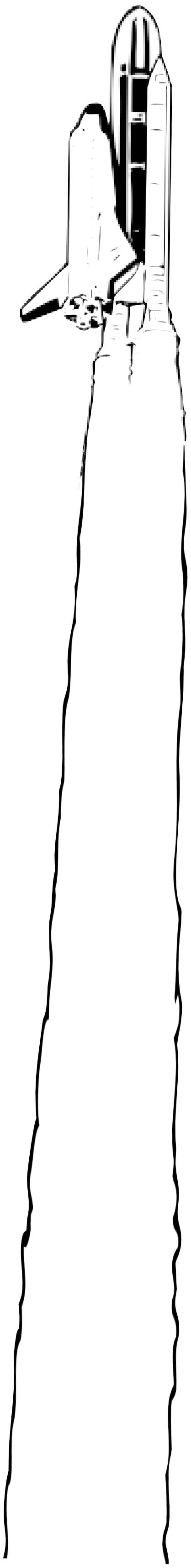




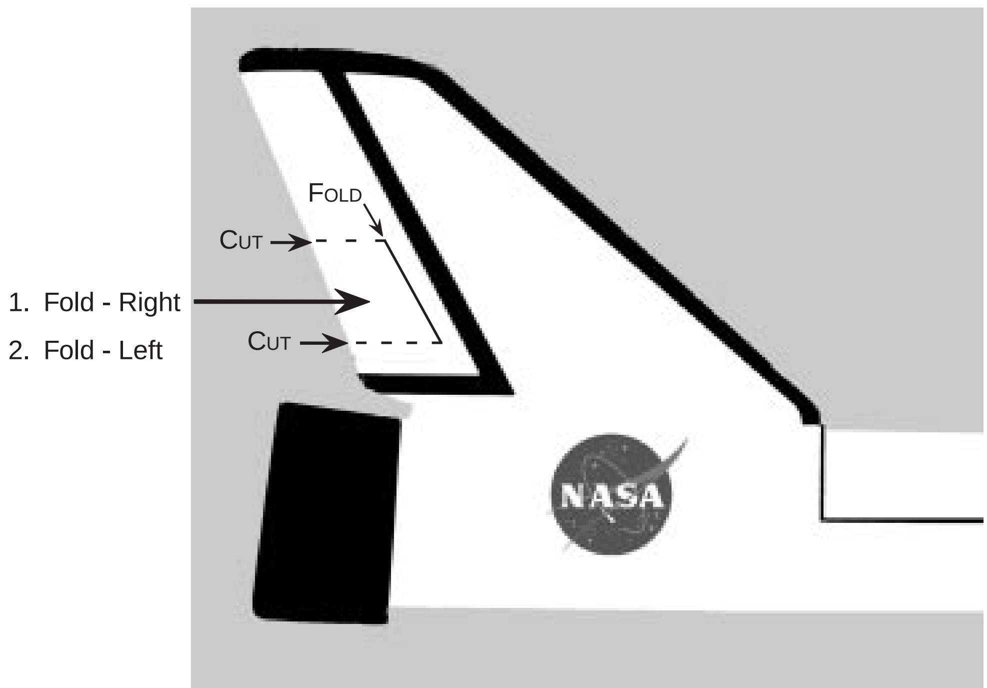
1. Left-Up
   then
2. Left-Down
   then
3. Left-Up
   then
4. Left-Down

1. Right-Up
   then
2. Right-Down
   then
3. Right-Down
   then
4. Right-Up

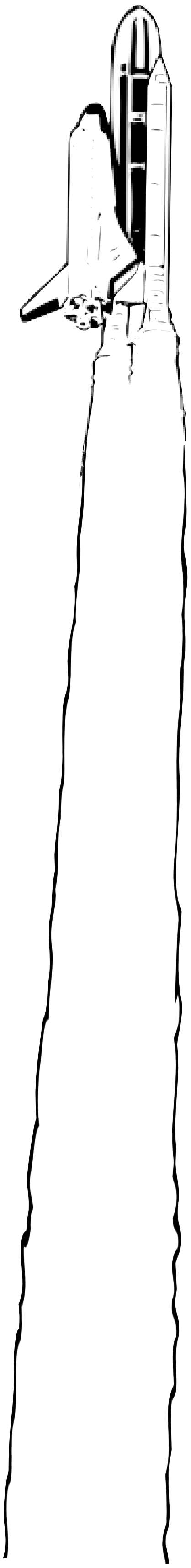
Experiment Procedure Experiment #3



SIDE VIEW

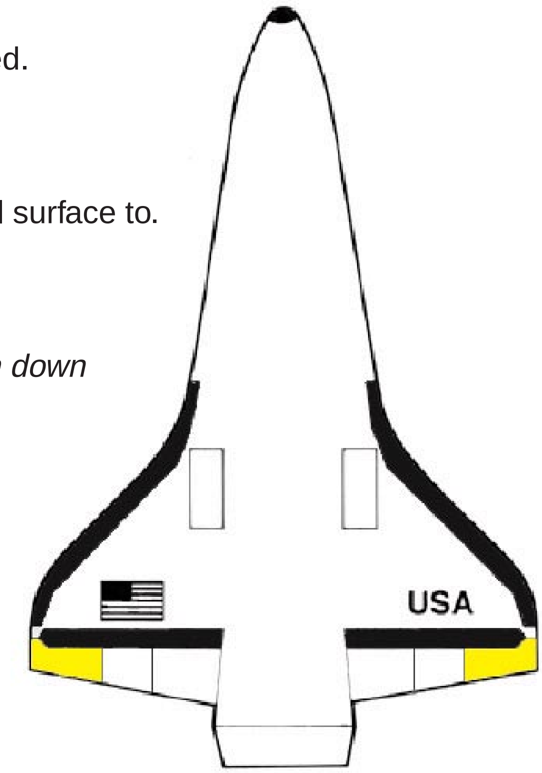


Control Surface Experiment Data Sheet #1 - Key



Directions: Follow the steps from your class procedure for Control Surface Experiment #1. As you test control surface #1 with your glider, complete this data sheet.

1. On the diagram shade the part of the plane you are testing.



2. Name the control surface you just shaded.

   outer elevon

3. Tell what position you moved that control surface to. (up, down, left, right, etc.)

   left outer elevon up, right outer elevon down

   or

   left outer elevon down, right outer elevon up

4. Briefly describe the glider's flight.

   the glider rolled left
   or
   the glider rolled right

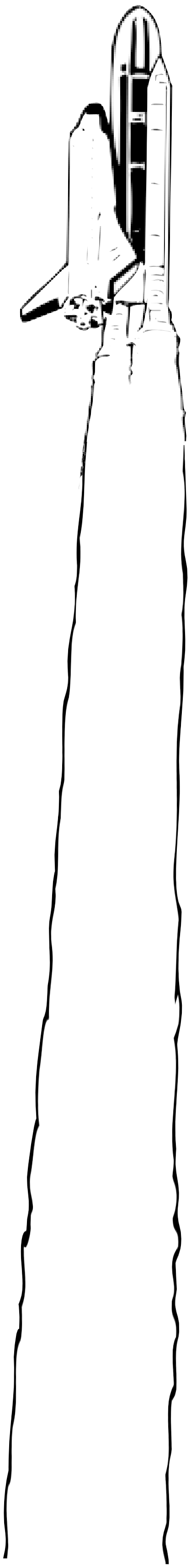
5. Draw the glider's flight path.

6. Circle the type of motion that this control surface controls.

   pitch yaw roll

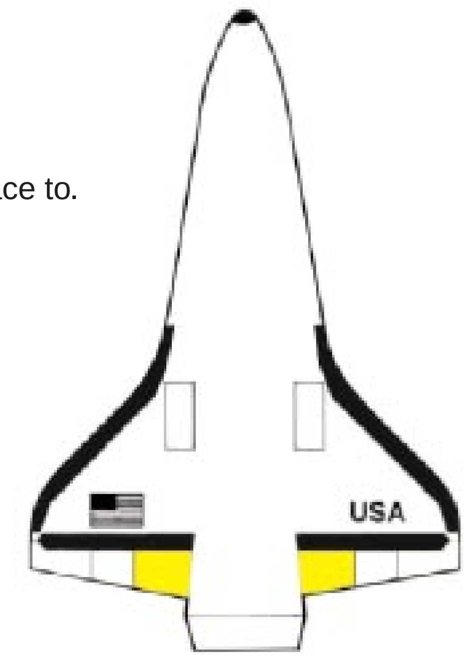
7. Use this space for any other observations you might have.

Control Surface Experiment Data Sheet #2 - Key



Directions: Follow the steps from your class procedure for Control Surface Experiment #2. As you test control surface #2 with your glider, complete this data sheet.

1. On the diagram shade the part of the plane you are testing.



2. Name the control surface you just shaded.

   inner elevon

3. Tell what position you moved that control surface to. (up, down, left, right, etc.)

   both inner elevon bent up

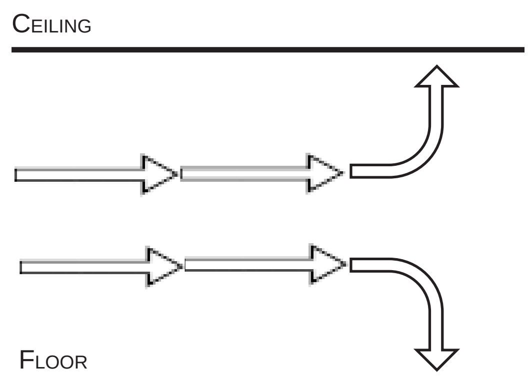
   or

   both inner elevon bent down

4. Briefly describe the glider's flight.

   the glider's nose pitched up
   or
   the glider's nose pitched down

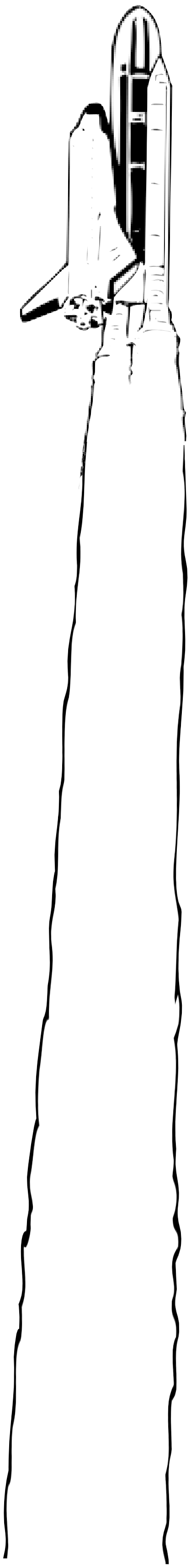
5. Draw the glider's flight path.



6. Circle the type of motion that this control surface controls.

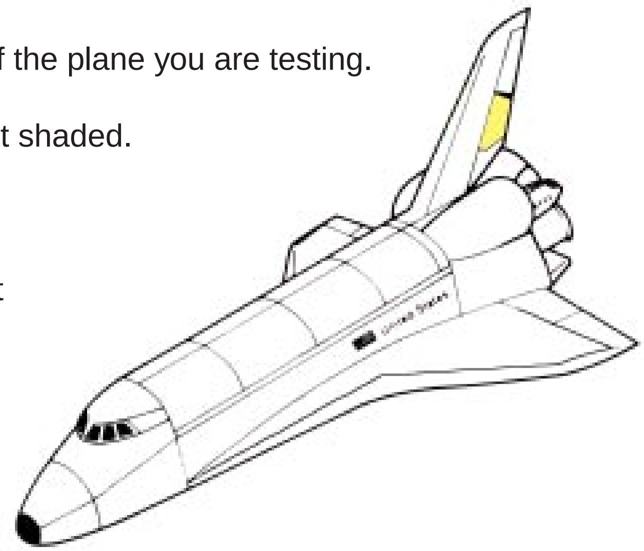
pitch yaw roll

7. Use this space for any other observations you might have.



Control Surface Experiment Data Sheet #3 - Key

Directions: Follow the steps from your class procedure for Control Surface Experiment #3. As you test control surface #3 with your glider, complete this data sheet.



1. On the diagram shade the part of the plane you are testing.

2. Name the control surface you just shaded.

   rudder

3. Tell what position you moved that control surface to (up, down, left, right, etc.)

   to the left

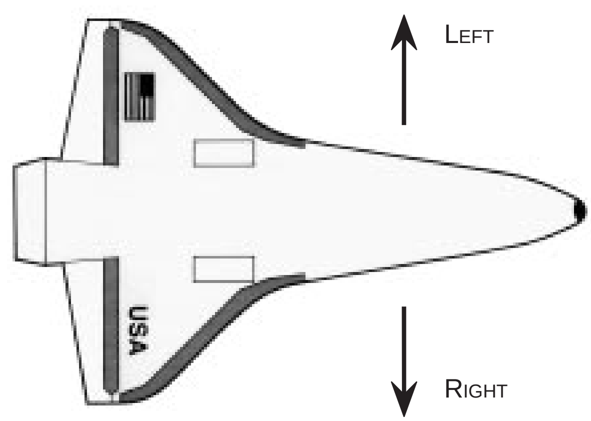
   or

   to the right

4. Briefly describe the glider's flight.

   the glider's nose yawed left
   or
   the glider's nose yawed right

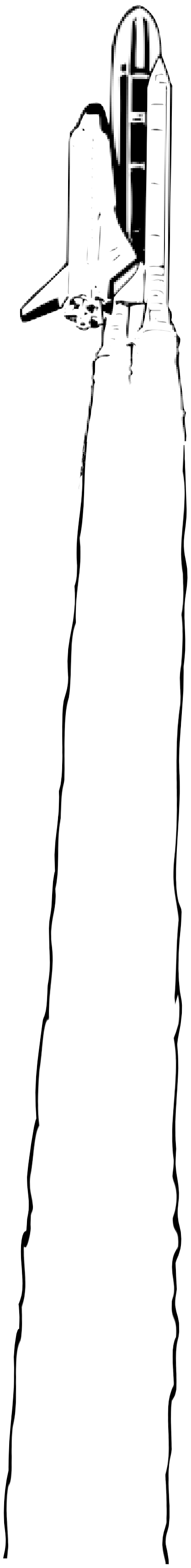
5. Draw the glider's flight path.



6. Circle the type of motion that this control surface controls.

   pitch yaw roll

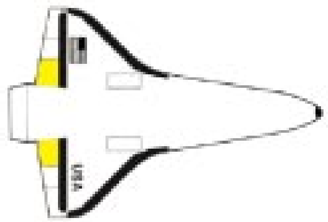
7. Use this space for any other observations you might have.



Experiment Conclusion Report - Key

Data

Control Surface #1	Position (in tandem, opposite) (up, down, right, left)	Motion (roll, pitch, yaw) Direction (up, down, left, right)

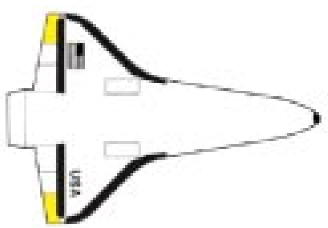


control surface:

____

left - up right - down	roll left (pronounced)
left - down right - up	roll right (pronounced)
both - down	pitch down
both - up	pitch up

Control Surface #2	Position (in tandem, opposite) (up, down, right, left)	Motion (roll, pitch, yaw) Direction (up, down, left, right)

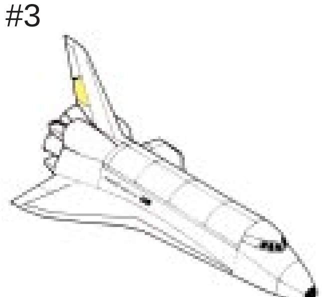


control surface:

____

left - up / right - down left - down / right - up	roll - left roll - right
both - down both - up	pitch - down flies straight & level longer with slight nose up

Control Surface #3	Position (in tandem, opposite) (up, down, right, left)	Motion (roll, pitch, yaw) Direction (up, down, left, right)

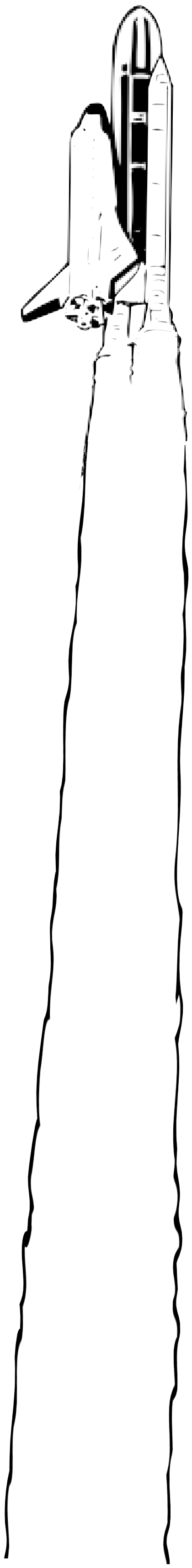


control surface:

____

right	yaw right
left	yaw left

Student Worksheet: Orbiter Control - Key



Directions: After reading “Orbiter Control”, answer each question below.

1. Explain in your own words why the orbiter is a “true aerospace vehicle”.

   An aerospace vehicle is a craft that cannot only fly “in the air” (or atmosphere), but also in space without having to change its form. The orbiter can do this.

2. Complete the chart below by naming the four basic control surfaces and what motions each one controls.

Control Surface	Motion Controlled
Elevons	roll, pitch
Rudder	yaw
Speed brake	forward motion
Body flap	pitch

3. Why does the orbiter have wide S-turns as part of its descent flight path?

   The wide S-turns help to slow its speed during descent by generating more drag with its positive pitch (nose up entry) and longer flight path.

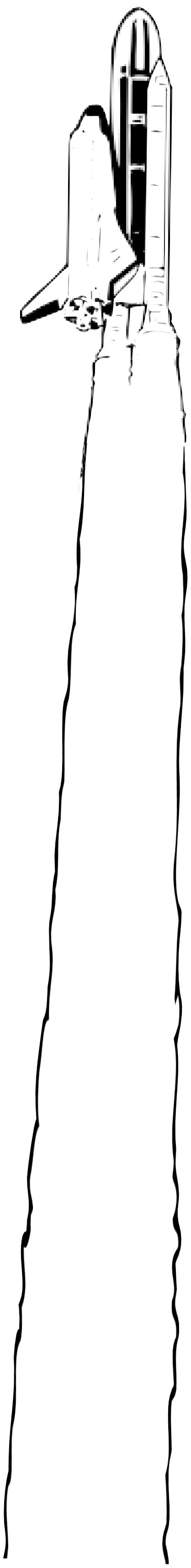
4. Give the orbiter’s fastest speed and slowest speed that it flies during its landing.

   Fastest speed: 28,000 km/h or 17,100 mph
   Slowest speed: 350 km/h or 210 mph

5. Why is the orbiter’s nose pitched positively (up) during most of its landing flight?

   This exposes the widest part of the orbiter to the oncoming airflow and generates more drag that slows its speed. It also concentrates the heat encountered during the descent onto the heat shields located on its underbelly. This protects the orbiter from burning up upon reentry.

Student Worksheet: Descent Control - Key

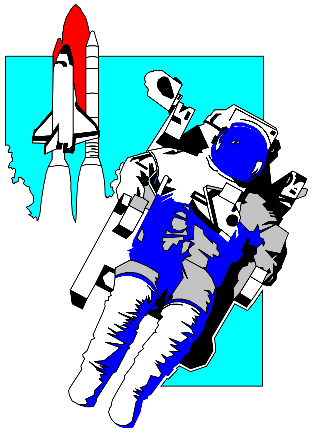


Directions: Using what you have learned about control surfaces on the orbiter and motions; give flying advice to the commander. At each numbered orbiter on the descent profile in the diagram (see next page), recommend to the commander the following flight instructions:

- motion(s) to be flown
- control surfaces to be used
- position of each control surface used

Complete the chart below with your information.

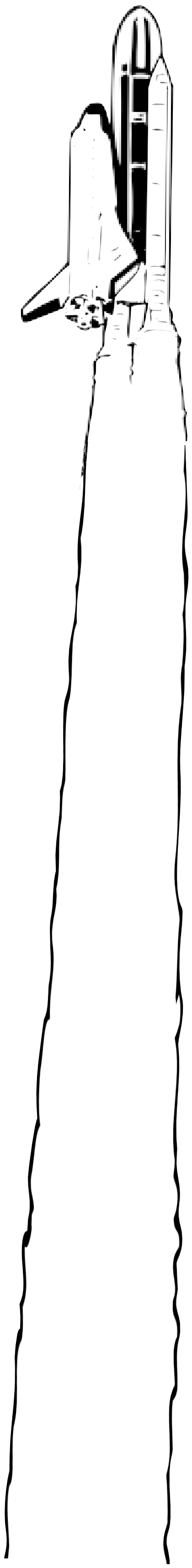
Orbiter	Motions	Control Surface(s)	Position of control surface
1	roll left slight yaw left	inner elevon outer elevon rudder	left - up / right down left - up / right down left
2	roll right slight yaw right	inner elevon outer elevon rudder	left - down / right up right
3	roll right slight yaw right	inner elevon outer elevon rudder	left - down / right up right
4	pitch - up	inner or outer elevon	both up



Student Science Activity: Everything's Under Control

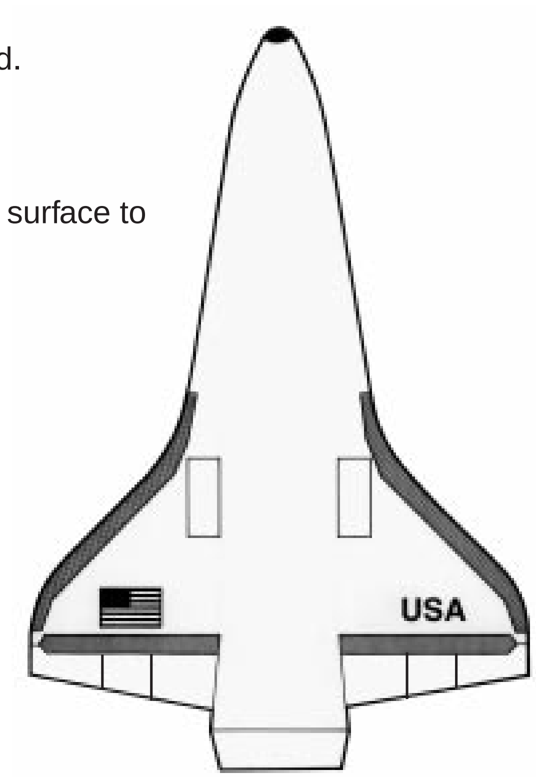
Student Handouts

Control Surface Experiment Data Sheet #1



Directions: Follow the steps from your class procedure for Control Surface Experiment #1. As you test control surface #1 with your glider, complete this data sheet.

1. On the diagram shade the part of the plane you are testing.
2. Name the control surface you just shaded.

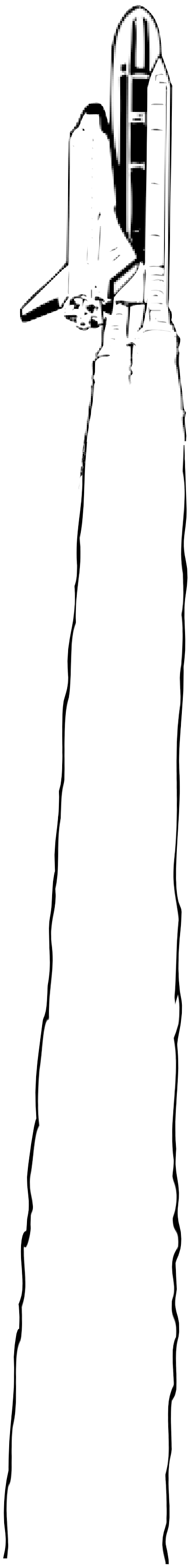


3. Tell what position you moved that control surface to (up, down, left, right, etc.)
4. Briefly describe the glider's flight.
5. Draw the glider's flight path.
6. Circle the type of motion that this control surface controls.

   pitch yaw roll

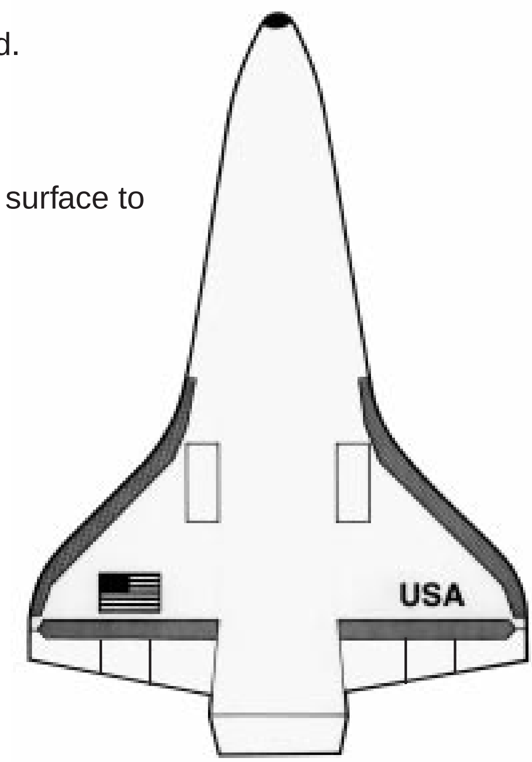
7. Use this space for any other observations you might have.

Control Surface Experiment Data Sheet #2



Directions: Follow the steps from your class procedure for Control Surface Experiment #2. As you test control surface #2 with your glider, complete this data sheet.

1. On the diagram shade the part of the plane you are testing.



2. Name the control surface you just shaded.

3. Tell what position you moved that control surface to (up, down, left, right, etc.)

4. Briefly describe the glider's flight.

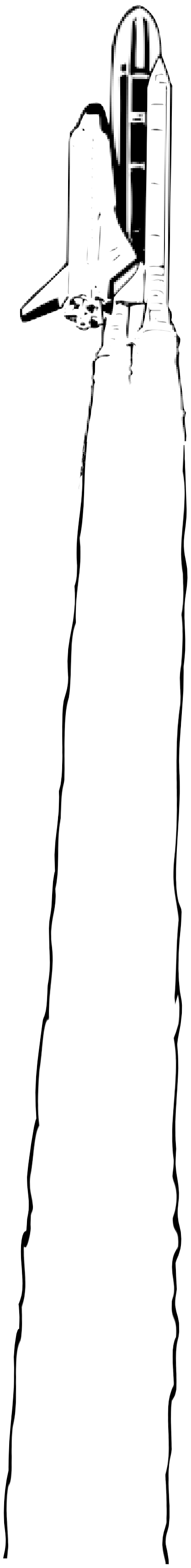
5. Draw the glider's flight path.

6. Circle the type of motion that this control surface controls.

   pitch yaw roll

7. Use this space for any other observations you might have.

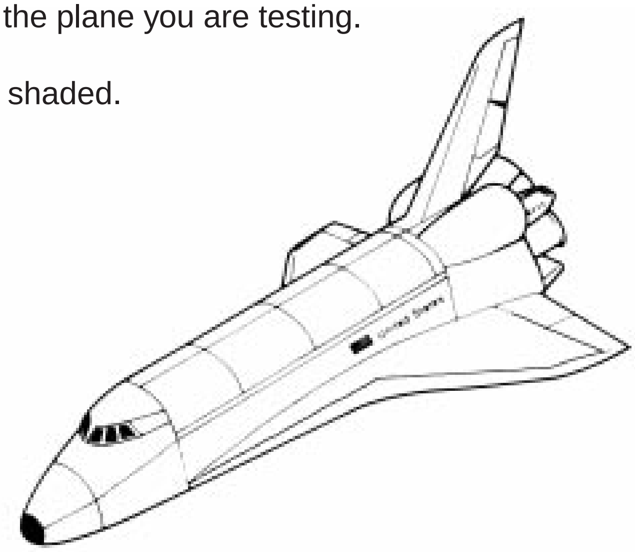
Control Surface Experiment Data Sheet #3



Directions: Follow the steps from your class procedure for Control Surface Experiment #3. As you test control surface #3 with your glider, complete this data sheet.

1. On the diagram shade the part of the plane you are testing.

2. Name the control surface you just shaded.



3. Tell what position you moved that control surface to. (up, down, left, right, etc.)

4. Briefly describe the glider's flight.

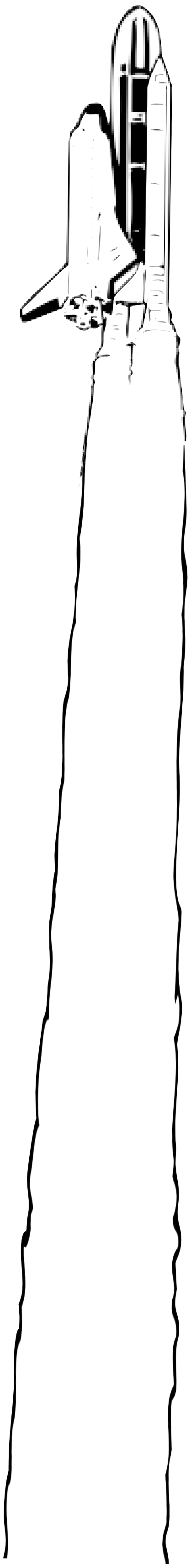
5. Draw the glider's flight path.

6. Circle the type of motion that this control surface controls.

   pitch   yaw   roll

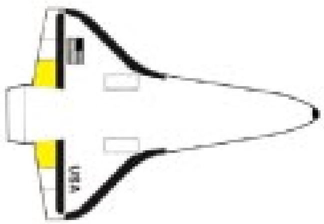
7. Use this space for any other observations you might have.

Experiment Conclusion Report



Data

Control Surface
#1



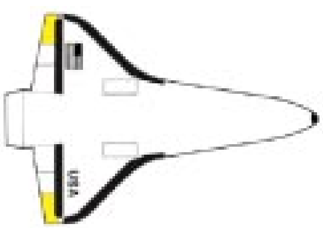
control surface:

____

Position
(in tandem, opposite)
(up, down, right, left)

Motion
(roll, pitch, yaw)
Direction
(up, down, left, right)

Control Surface
#2



control surface:

____

Position
(in tandem, opposite)

(up, down, right, left)

Motion
(roll, pitch, yaw)
Direction
(up, down, left, right)

Control Surface
#3

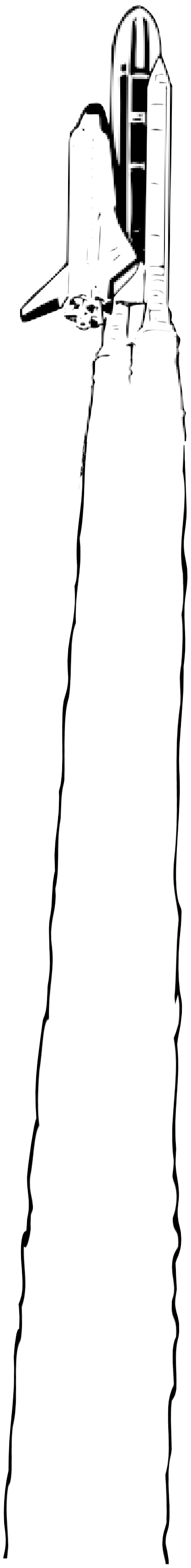
control surface:

____

Position
(in tandem, opposite)
(up, down, right, left)

Motion
(roll, pitch, yaw)
Direction
(up, down, left, right)

Student Informational Reading: Orbiter Control

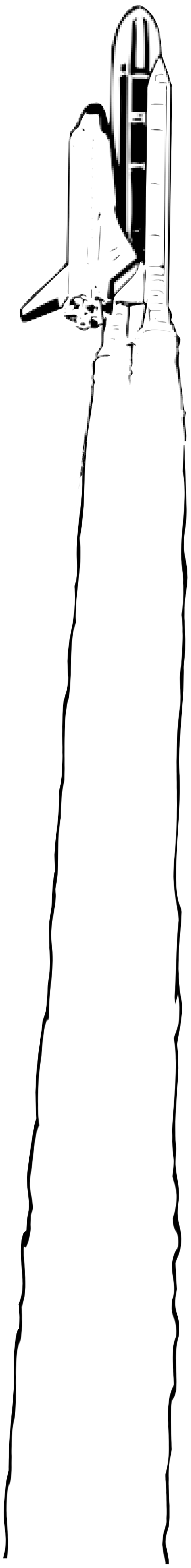


The space shuttle orbiter is truly an aerospace vehicle. It takes off using rockets, it orbits the earth as a spacecraft, and glides to the earth's surface as an airplane. During launch and its orbit of the earth, the orbiter does not make use of its airplane control surfaces at all. Because space is a vacuum, there is no air and therefore no air molecules through which the orbiter could fly. Remember that in order for there to be a difference in air pressure between the air flowing over a wing and the air flowing under a wing, there has to be air! No air, no air pressure, no lift! So the orbiter's wings and control surfaces are useless in space, but once below an altitude of about 96.9 km (60 miles), they can be used just like the control surfaces on an airplane.

The orbiter has 4 basic control surfaces. They are the split rudder, elevons, speed brake and the body flap. The split rudder is located on the tail section of the orbiter which is called the vertical stabilizer. It is used to move the nose of the orbiter to the pilot's right or left. This side-to-side motion of the nose is called yaw. Because of the orbiter's delta wing configuration, it does not have elevators or ailerons. It has a combination of these two airplane control surfaces: elevons. The orbiter has two sets of these elevons. It has an inner set and an outer set located on the delta wings. The inner elevons control the motions of pitch and roll. The outer elevons also control the motions of pitch and roll. The difference between the inner and outer elevons is that the outer elevon is used primarily at higher (faster) speeds, while the inner elevon is used primarily at the lower (slower) speeds.

The split rudder is a control surface unique to the orbiter. The split rudder has two hinged surfaces which can move together to the left and right (functioning as a rudder). It can also split apart or open (functioning as a speed brake). When deflected (or opened) it changes the way the air flows around the tail section of the orbiter. In doing this, it creates drag that slows the orbiter's speed. Because of the orbiter's need to be able to glide through the atmosphere at speeds from hypersonic to subsonic, the speed brake is used along with the wide S-turns to slow the orbiter's speed as it descends. The body flap (located just underneath the engines) is also a control surface unique to the orbiter. It is used to help trim the orbiter's attitude. That means that the body flap is used to keep the orbiter in its proper flight position to maintain its course. These four basic control surfaces (rudder, elevons, speed brake and body flap) work together to keep everything under control as the orbiter rushes towards its runway.

Student Informational Reading: Orbiter Control (continued)

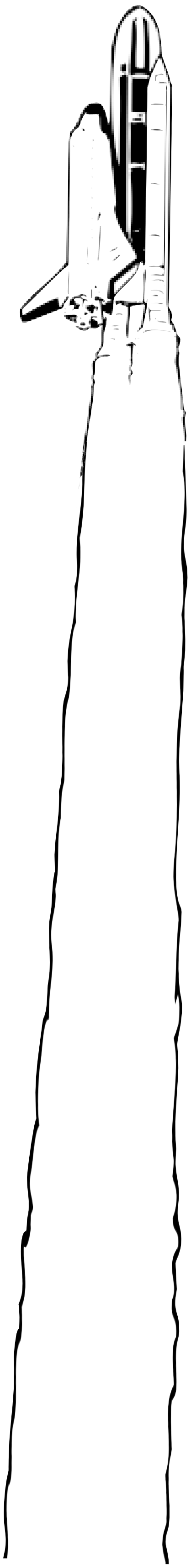


Let's follow closely a typical landing of the orbiter and see how and when each control surface is used during this phase of the flight. At about an altitude of 96.6 km (60 miles), the orbiter encounters the fringes of the earth's atmosphere moving at a speed of 28,500 km/h (17,100 mph) with its nose pitched to a 30 degree angle. Less than 8 minutes later, the orbiter has already descended to an altitude of 77 km (46.2 miles) and is maintaining a speed of 28,000 km/h (16,800 mph). At approximately this altitude the air is dense enough for the control surfaces on the orbiter to operate. The body flap, elevons, split rudder and speed brake are put into use.

The orbiter begins its series of S-turns by making a broad sweeping roll to the right which is done to slow its speed as it descends dramatically from an altitude of 70 km (42 miles) to 33 km (19.8 miles). During this descent it also slows its speed from 28,000 km/h (17,100 mph) to 4,800 km/h (2,880 mph). During speeds above 8,180 mph the elevons and the body flap are in the up position. At a speed of 8,720 km/h (5,450 mph) the speed brake is deflected to a full-out position. This causes the nose to pitch up and allows the elevons to be put in the down position while the orbiter continues to slow its speed while descending. At a speed of 3,272 km/h (2,045 mph) the elevons are returned to an up position and the speed brake is moved to a smaller deflection (or closed slightly) to reduce the positive pitch angle (upward pitch) of the nose.

At an altitude of 21 km (12.6 miles) flying at a speed of 1,700 km/h (1,020 mph), the orbiter enters the Terminal Area Energy Management (TAEM) phase of its flight. During this phase of its landing, its energy (lift versus drag) is balanced for the final approach. Since the orbiter does not use engine power to land, it has only one opportunity to land. It cannot abort and fly around the runway for another try because it has no engine power to propel it upward again. It is important that during the TAEM phase the commander achieves a balance between lift and drag to ensure the best possible landing. At 15 km (9 miles) above the earth's surface, the orbiter slows as it passes through the sound barrier. At 3 km (1.8 miles) in altitude, the orbiter has entered its final approach phase with a 10 degree angle of attack as it maintains a steep glide slope of 21 to 24 degrees. To compare, a jetliner on its final approach phase approaches a runway at a glideslope of 2 to 3 degrees. While flying at subsonic speed, the speed brake is slightly deflected to continue to slow the

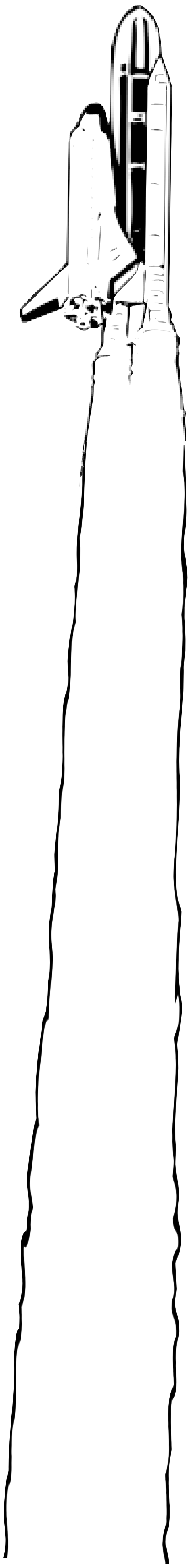
Student Informational Reading: Orbiter Control (continued)



orbiter's speed. The body flap is used to assist in trimming the orbiter's attitude. As the orbiter descends to about 550 meters (about 1,650 feet) above the ground, the orbiter's angle of attack is slowly lowered to 3 degrees and the glideslope is flattened from 24 degrees to 3 degrees. During this part of the landing the orbiter's onboard computers are assisted by a landing system that uses a microwave scanning beam. About 2 km (1.2 miles) from the touchdown point, the main landing gear is lowered and the flare maneuver is used which pitches the nose up 10 degrees. The orbiter's speed slows to about 350 km/h (210 mph) as it touches down on the runway. The parachute is deployed and the orbiter rolls to a stop about 2.5 km (1.5 miles) down the runway.

So we see how this unique aerospace vehicle travels from the outer reaches of the atmosphere to landing on a runway far below. We see how the control surfaces work together to guide the delta-winged glider from hypersonic speeds to subsonic speed, bringing it to a halt with the deployment of its parachute at its final destination. It is the orbiter's remarkable aerospace glider design that has made it a dependable part of the space transportation system linking the earth with space.

Student Worksheet: Orbiter Control



Directions: After reading "Orbiter Control", answer each question below.

1. Explain in your own words why the orbiter is a "true aerospace vehicle".

2. Complete the chart below by naming the four basic control surfaces and what motions each one controls.

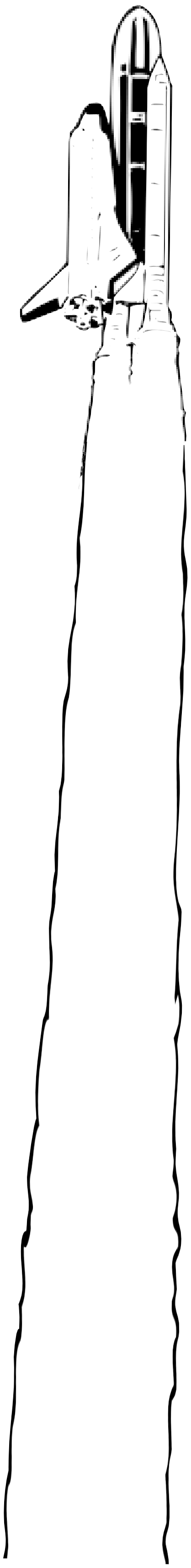
Control Surface	Motion Controlled

3. Why does the orbiter have wide S-turns as part of its descent flight path?

4. Give the orbiter's fastest speed and slowest speed that it flies during its landing.

5. Why is the orbiter's nose pitched positively (up) during most of its landing flight?

Student Worksheet: Descent Control



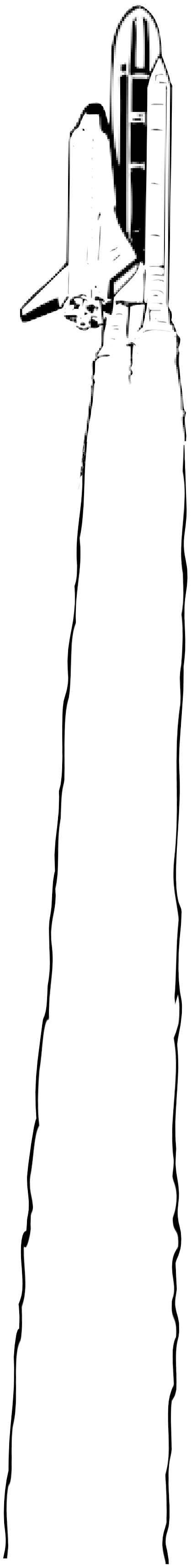
Directions: Using what you have learned about control surfaces on the orbiter and motions; give flying advice to the commander. At each numbered orbiter on the descent profile in the diagram (see next page), recommend to the commander the following flight instructions:

- motion(s) to be flown
- control surfaces to be used
- position of each control surface used

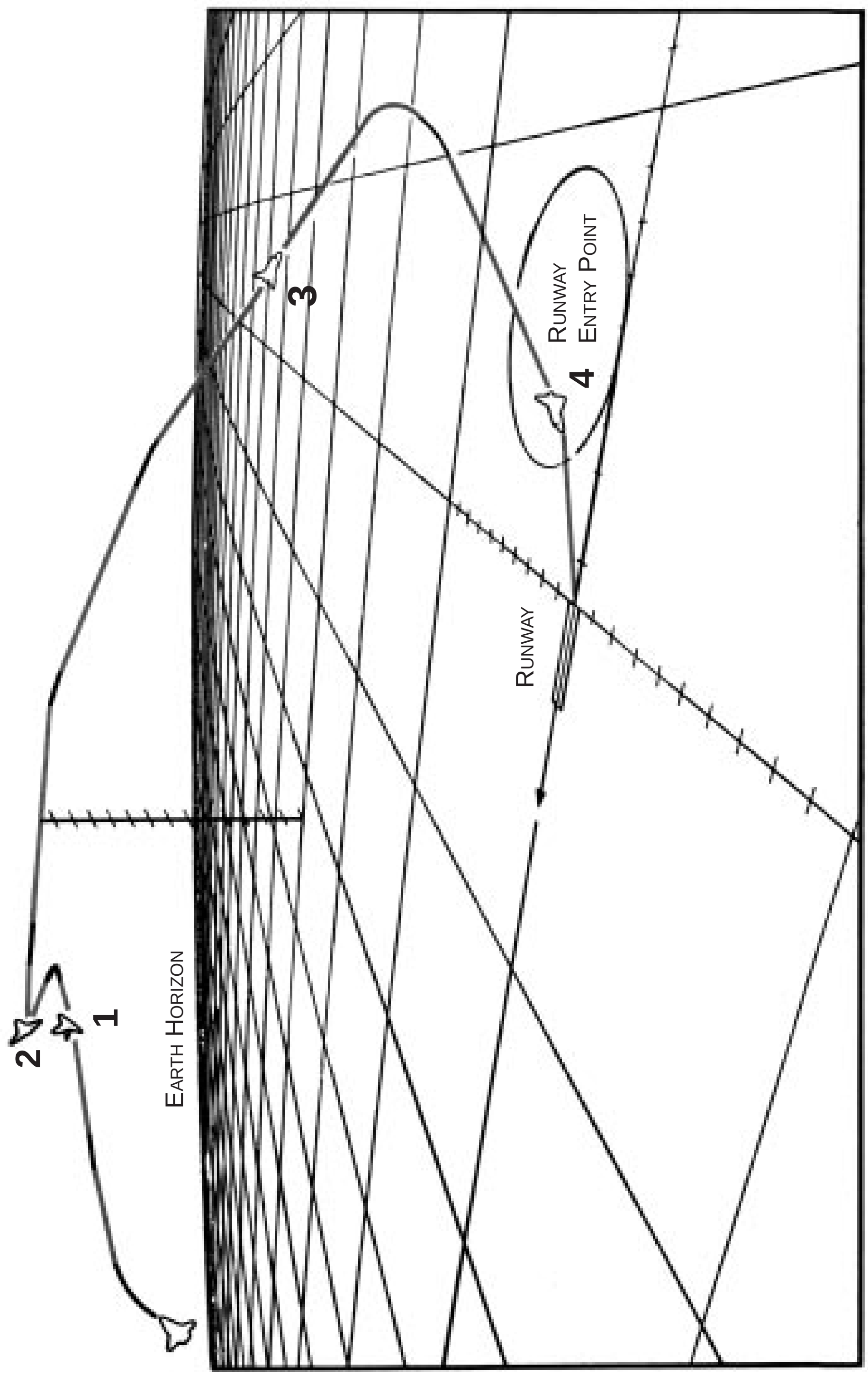
Complete the chart below with your information.

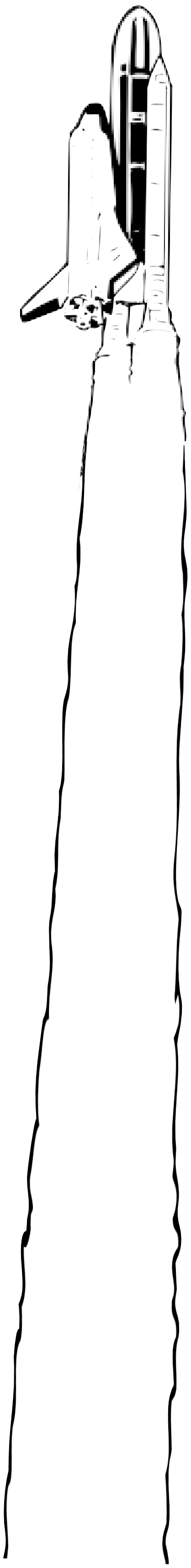
Orbiter	Motions	Control Surface(s)	Position of control surface
1			
2			
3			
4			

Student Worksheet: Descent Control (continued)



Flight Profile





Self - Evaluation Check-up

Directions: Rate yourself and your work. On a scale of one (low) to ten (high), tell how well did you do on each part of this activity.

Name of Activity: **Everything's Under Control**

A) Following Directions

I skipped around a lot because I did not follow directions.	I closely followed the directions and did the steps in proper order.

1 5 10

B) Using Time Wisely

I misspent a lot of time.	I stayed on task the whole time.

1 5 10

C) Recording Observations / Information

I did not write much.	I wrote a lot and included everything I observed.

1 5 10

D) Working Well With Others

I got along only part of the time.	I got along most of the time.

1 5 10

E) Discussing Ideas / Results with Others

I did not add much to the discussion.	I contributed lots of ideas to the discussion.

1 5 10

F) List two things you learned about flight from this activity.